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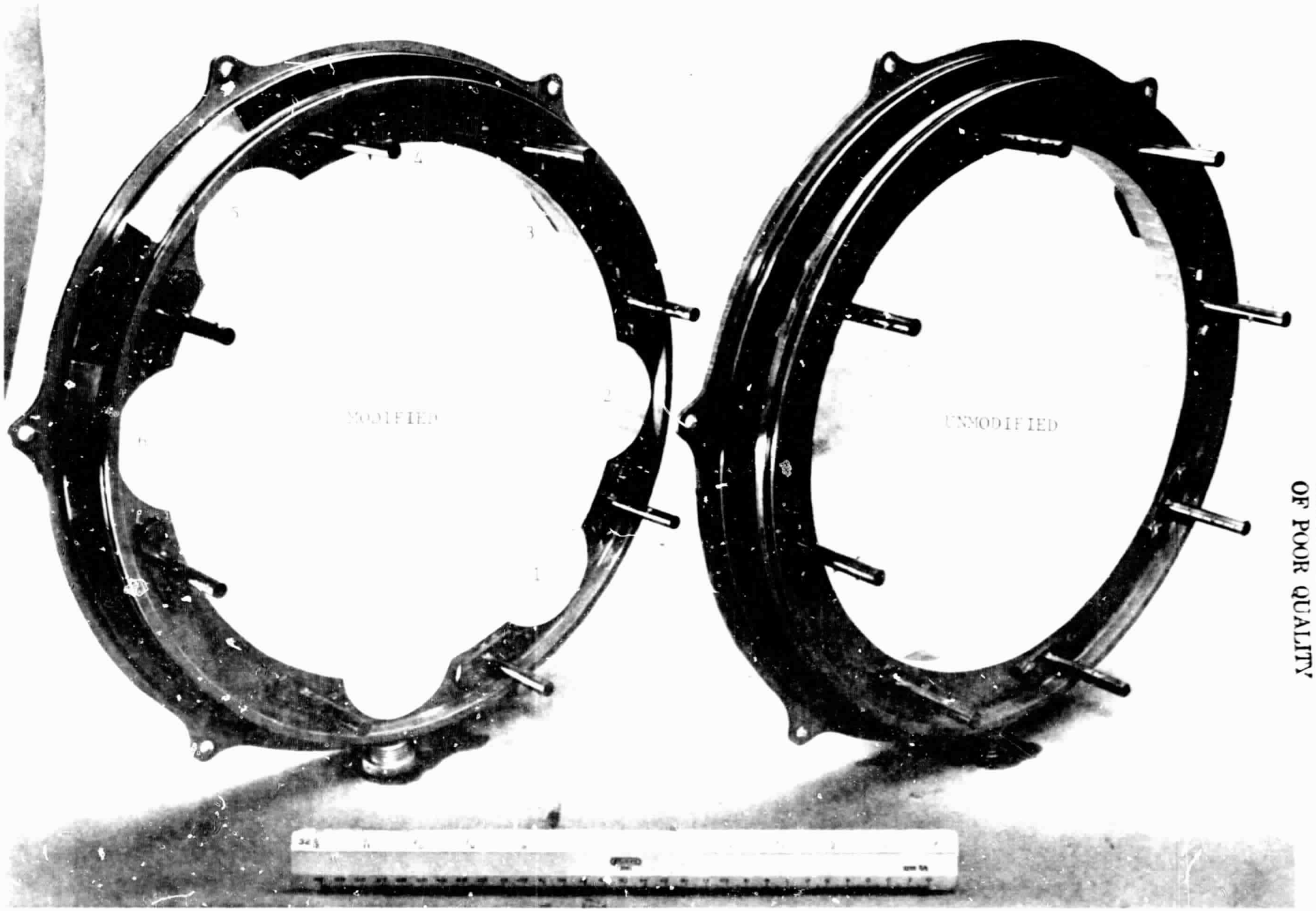

Figure 5.3-2. QCSEE Main Reduction Gear - OTW Unit Oil Manifold Modification

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NASA CR-134669

CW-WR-77-008

QUIET CLEAN SHORT-HAUL EXPERIMENTAL ENGINE
(QCSEE)
MAIN REDUCTION GEARS
TEST PROGRAM

Final Report

by

Curtiss-Wright Corporation
Under Subcontract to General Electric Co.

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EXPERIMENTAL ENGINE (QCSEE) MAIN REDUCTION
GEARS TEST PROGRAM Final Report
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Prepared For

National Aeronautics and Space Admini

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NASA Lewis Research Center
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16. Abstract

This report covers the testing of two similar but different gear ratio Curtiss-Wright designed and built epicyclic star configuration reduction gears in a back-to-back rig. Testing demonstrated satisfactory operation prior to delivery to the General Electric Company for installation as the main reduction gears driving fans in Quiet Clean Shorthaul Experimental Engines (QCSEE). The under-the-wing (UTW) engine reduction gears which have a ratio of 2.465:1 and a design rating of 9712 kw (13,019 horsepower) at 3157 rpm fan speed were operated at up to 105% speed at 60% torque and 100% speed at 125% torque. The over-the-wing (OTW) engine reduction gears which have a ratio of 2.062:1 and a design rating of 12,615 kw (16,910 horsepower) at 3861 rpm fan speed were operated at up to 95% speed at 50% torque and 80% speed at 109% torque. Satisfactory operation was demonstrated at powers up to 12,172 kw (16,316 hp), mechanical efficiency up to 99.1% (UTW), and a maximum gear pitch line velocity of 112 m/s (22,300 fpm) with a corresponding star gear spherical roller bearing DN of 0.85×10^6 (OTW). Oil and star gear bearing temperatures, oil churning, heat rejection and vibratory characteristics were acceptable for engine installation.

17. Key Words (Suggested by Author(s))

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ABSTRACT

This report covers the testing of two similar but different gear ratio Curtiss-Wright designed and built epicyclic star configuration reduction gears in a back-to-back rig. Testing demonstrated satisfactory operation prior to delivery to the General Electric Company for installation as the main reduction gears driving fans in Quiet Clean Shorthaul Experimental Engines (QCSEE). The under-the-wing (UTW) engine reduction gears which have a ratio of 2.465:1 and a design rating of 9712 kW (13,019 horsepower) at 3157 rpm fan speed were operated at up to 105% speed at 60% torque and 100% speed at 125% torque. The over-the-wing (OTW) engine reduction gears which have a ratio of 2.062:1 and a design rating of 12,615 kW (16,910 horsepower) at 3861 rpm fan speed were operated at up to 95% speed at 50% torque and 80% speed at 109% torque. Satisfactory operation was demonstrated at powers up to 12,172 kW (16,316 hp), mechanical efficiency up to 99.1% (UTW), and a maximum gear pitch line velocity of 112 m/s (22,300 fpm) with a corresponding star gear spherical roller bearing DN of 0.85×10^6 (OTW). Oil and star gear bearing temperatures, oil churning, heat rejection and vibratory characteristics were acceptable for engine installation.

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1.0 SUMMARY

Two similar but different gear ratio epicyclic star configuration main reduction gears were designed and built by Curtiss-Wright for the General Electric Quiet Clean Shorthaul Experimental Engines (QCSEE). The unit for the under-the-wing (UTW) engine has a gear reduction ratio of 2.465:1 and a design rating of 9712 kW (13,019 horsepower) at 3157 rpm fan speed. The unit for the over-the-wing (OTW) engine has a gear reduction ratio of 2.062:1 and a design rating of 12,615 kW (16,910 horsepower) at 3860 rpm fan speed. The two units have identical input, output, support and lubricant supply interfaces with the engine.

Design features common to both units include the sun gear supported by a double diaphragm coupling, a fixed support for the star gears, the star gears supported by double row spherical roller bearings with the outer race integral with the star gear, and the ring gear connected by a loose spline to the fan shaft. The UTW unit has six star gears and an operating gear pitch line velocity of 97.5 meters/second (19,200 feet/minute) at the design 100% speed. The OTW unit has eight star gears and an operating gear pitch line velocity of 119.3 meters/second (23,480 feet/minute) at the design 100% speed.

Primary objectives of the test program were to demonstrate satisfactory operation and to determine operating characteristics of each of the two reduction gear designs at flight spectrum and experimental engine speeds, powers and oil inlet temperatures prior to installation of the units in aircraft development engines. Specific objectives were:

a. Verify satisfactory bearing performance.
b. Verify adequate gear lubrication, absence of scoring.
c. Verify satisfactory gear tooth contacts over the operating torque range.
d. Verify oil flow requirements.
e. Determine heat rejection rates and reduction gear efficiencies.
f. Identify natural frequency characteristics of the ring gear.

Testing was conducted with two essentially identical units installed in a back-to-back test rig and torque loaded to simulate engine operating conditions. The rig design simulated some engine reduction gear cavity and oil scavenging characteristics.

The UTW main reduction gears accumulated a total operating time of about 48.8 hours in the Hopkinson back-to-back test rig. Satisfactory maximum power operation was demonstrated at 100% design speed with 125% torque load, while transmitting a total power of 12,172 kW (16, 316 hp). Satisfactory maximum speed operation was demonstrated with 50% torque load up to 105% design speed, corresponding to a maximum gear pitch line velocity of 103 m/s (20,360 fpm), and a maximum star gear spherical roller bearing DN of 0.79 x 10^6 (based on bearing bore (stationary) in millimeters and outer race rotational speed in rpm). Measured UTW mechanical efficiency at 100% design speed and power was 98.9%, and increased to 99.1% with 125% torque.

The OTW main reduction gears accumulated a total operating time of about 36 hours in the Hopkinson back-to-back test rig. Satisfactory maximum power operation was demonstrated at 90% design speed with 100% design torque, while transmitting a total power of 11,342 kW (15,204 hp). Test rig power limitations restricted high speed, high power OTW operation. Satisfactory OTW maximum speed operation was demonstrated with 50% torque load up to 95% design speed, corresponding to a maximum gear pitch line velocity of 112 m/s (22,300 fpm), and a maximum star gear spherical roller bearing DN of 0.85 x 10^6. Measured OTW mechanical efficiency at 90% speed and 100% torque was 98.7%.

Two areas of concern, which would benefit from future investigation and/or development, include a slightly higher than anticipated power loss, attributable to excessive oil churning, and star gear axial movement or "wobble".

Both the UTW and OTW reduction gears were delivered to the General Electric Company, Aircraft Engine Group, at Evendale, Ohio, for subsequent installation and test in the QCSEE UTW and OTW aircraft turbofan development engines, respectively.

2.0 INTRODUCTION

The Quiet Clean Short-Haul Experimental Engine (QCSEE) Program is being conducted by the General Electric Company Aircraft Engine Group, under NASA prime contract NAS3-18021. The QCSEE program provides for the design, fabrication, and testing of two experimental high bypass geared turbofan engine and propulsion systems for short-haul passenger aircraft. Overall engine and propulsion system detailed design characteristics are presented for the UTW Engine in NASA CR-134847 (GE) ref. (1); and for the OTW Engine in NASA CR 134848 (GE) ref. (2).

Both engines utilize a lightweight turbine engine with a geared slower speed fan. Two similar engine-to-fan speed reducer gears but with different ratios were designed by the Power Systems Group, Curtiss-Wright Corporation under sub-contract to General Electric Company. These epicyclic star configuration reduction gear designs are based on the concept of the primary stage of a reduction gear developed by Curtiss-Wright for the Curtiss-Wright YT-49 and TP-51 turboprop engines. QCSEE requirements were in accordance with General Electric Specification M50TF1611 and the superseding Specification M50TF1672, ref. (3). The under-the-wing (UTW) engine reduction gear has a ratio of 2.465:1 and a 100% power and speed rating of 9712 kW (13,019 hp) at 3157 rpm fan speed. The over-the-wing (OTW) engine reduction gear has a ratio of 2.062:1 and 100% power and speed rating of 12,615 kW (16,910 hp) at 3860 rpm fan speed. Reduction gear design details are covered in Quiet Clean Short-haul Experimental Engine Main Reduction Gears Detailed Design Final Report, NASA CR-134872 (C-W), ref. (4).

Two complete sets of UTW engine reduction gears and three complete sets of OTW engine reduction gears were fabricated by Curtiss-Wright for rig testing by Curtiss-Wright and subsequent installation in engines by General Electric.

A separate star gear spherical roller bearing component test program was conducted by Curtiss-Wright to ensure satisfactory bearing operation prior to testing in the gear test rig. Detailed spherical roller bearing test results are reported in NASA CR-134890, "Main Reduction Gears Bearing Development Program Final Report", ref. (5) (C-W).

A back-to-back locked torque test rig simulating certain engine reduction gear cavity and oil scavenging characteristics was designed and procured. The planned test schedule defined in Section 4, Quality Assurance, of Specification M50TF1672 specified 50 hours of rig testing for the two UTW units, 160 hours of rig testing for two OTW units and 10 hours of rig testing for the third OTW unit with one of the previously tested OTW units.

The actual test schedule and test conditions accomplished deviate from the planned schedule because of effort being redirected to investigations of oil churning and other conditions encountered during this test program.

3.0 REDUCTION GEAR CHARACTERISTICS

3.1 General

The QCSEE UTW and OTW main reduction gears are similar but different ratio star configuration units designed with identical engine interfaces for installation between the turbine and fan shafts in the engine housing. Cross section views and identification of parts for the UTW and OTW reduction gear units are shown by Figure 3.1-1 and Figure 3.1-2, respectively.

The major reduction gear components are:

- a. Fixed star gear trunnion support
- b. Diaphragm type sun gear coupling
- c. Sun gear
- d. Star gears
- e. Ring gear
- f. Lubrication system components

In the engine installation the star gear trunnion support is attached to a fixed engine housing member. The power input to the reduction gear is through the sun gear which is supported by a flexible diaphragm type coupling attached to a similar coupling member on the engine turbine shaft. A lubricated clearance fit spline connects the coupling and sun gear. The star gears which mesh with the sun gear and ring gear are supported on the trunnions by spherical roller bearings which have the outer race integral with the gear. The power output is through the ring gear which is supported in the engine fan shaft by a clearance fit spline. The gear rims and attachments are designed for controlled deflections over a broad load range which together with gear support flexibility and accurate machining dimensional control provide equalization of gear tooth loading.

Lubrication of the gearing is provided from the engine system through a single connecting tube to an oil manifold attached to the star gear trunnion support. An annular passage distributes the oil to the individual trunnions for star gear bearing lubrication through radial passages in the trunnions and bearing inner races and to spray tubes which provide lubrication and cooling to the sun and star gear teeth. Two pads on the oil manifold and special sleeves in two trunnions are provided for supplying oil to the engine fan shaft bearings.

Data applicable specifically to the UTW unit or OTW unit are provided in subsequent Sections 3.2 and 3.3, respectively.

3.2 UTW Unit

The UTW engine reduction gear has a ratio of 2.465:1 and a current 100% power and speed rating of 9712 kW (13,019 hp) at 3157 rpm fan speed, revised from the original design 100% power and speed rating of 9781 kW (13116 hp) at 3143 rpm fan speed. This unit has six equally spaced star gears. The star gear trunnion length provides for the installation of a fan variable pitch mechanism (VPM) support clamped between the bearing nut and the bearing inner race. A photograph of the UTW reduction gears with a simulated VPM support installed

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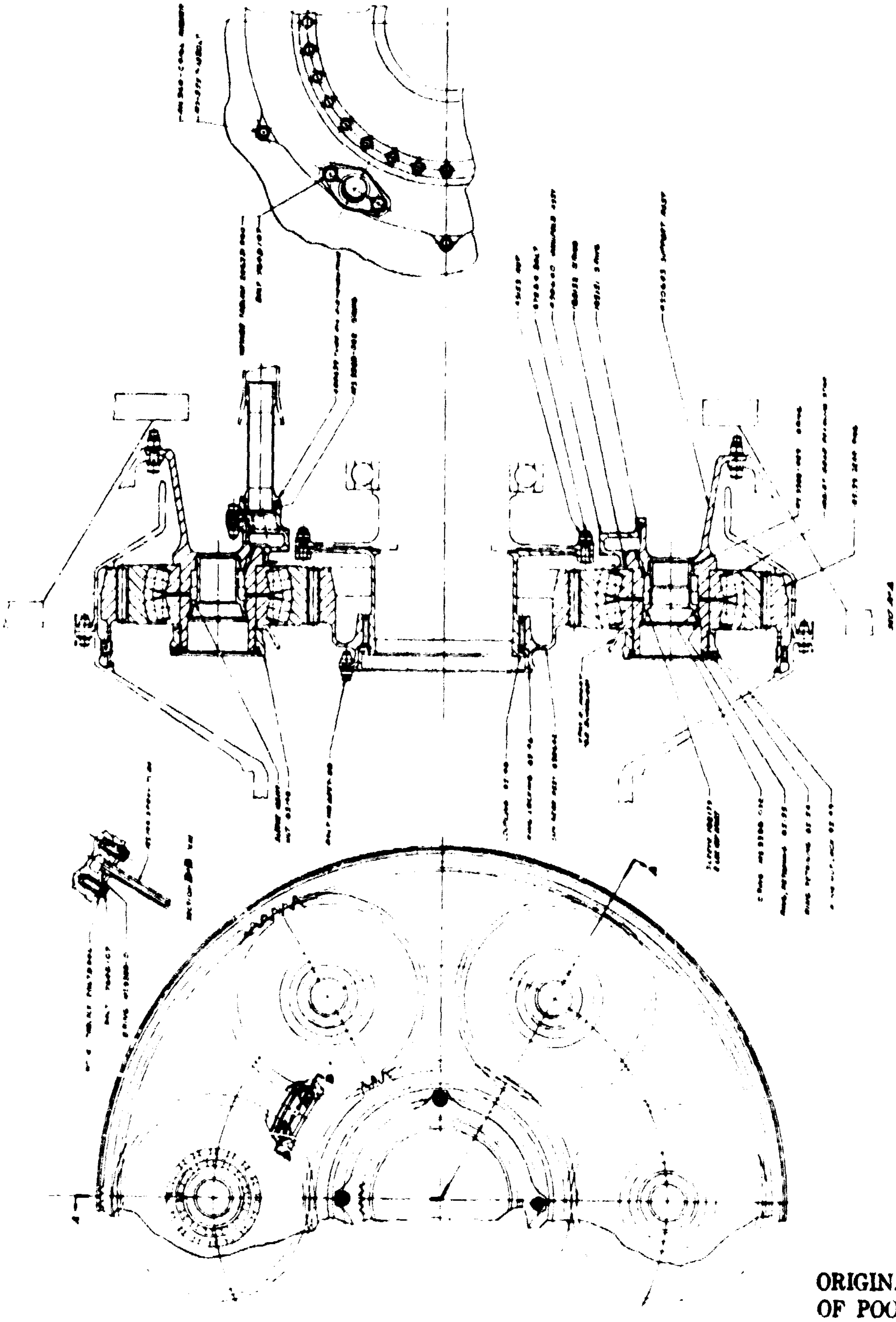

Figure 3.1-1 QCSEE Main Reduction Gear Under-The-Wing (UTW) Unit

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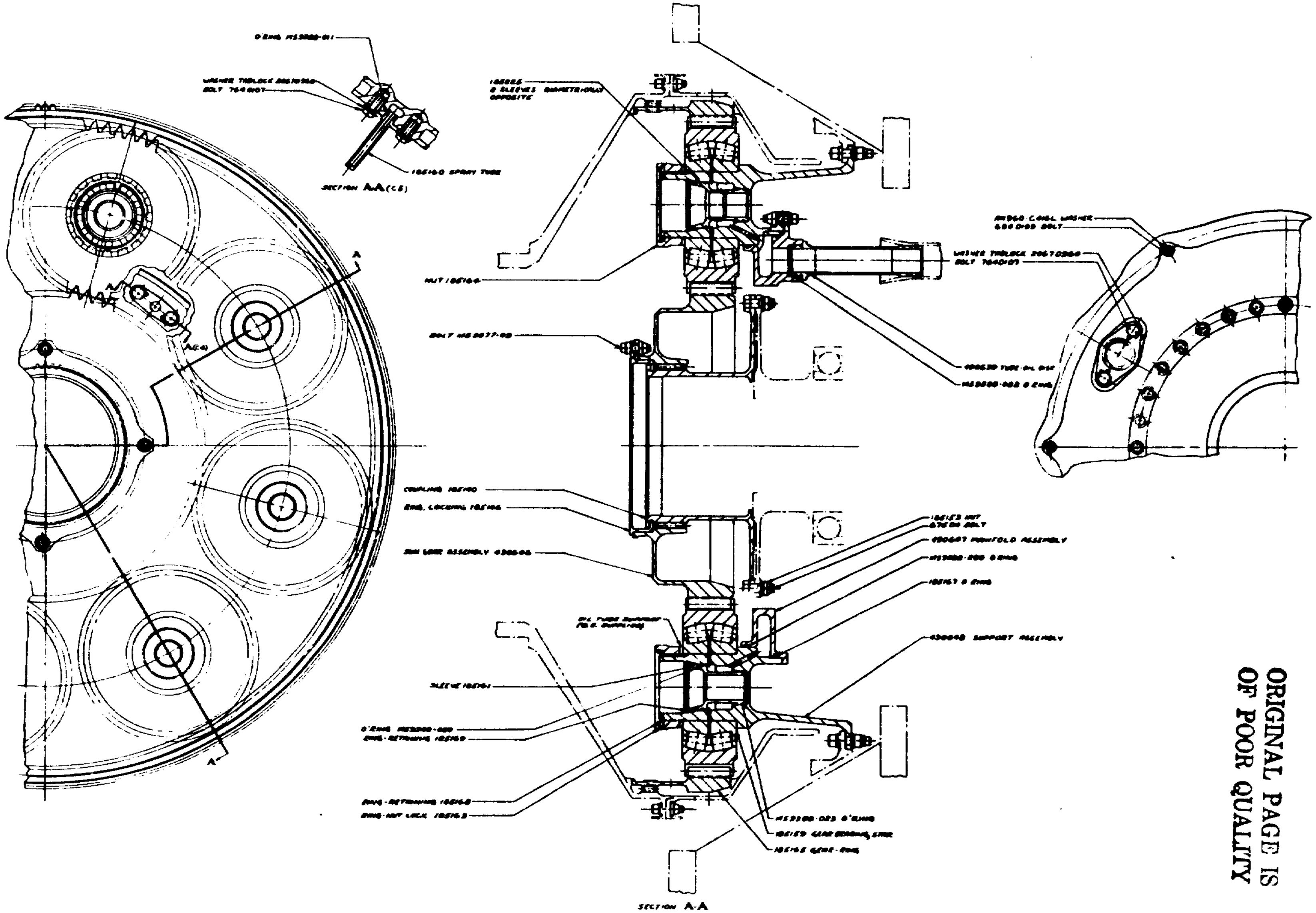


Figure 3.1-2 QCSEE Main Reduction Gear
Over-The Wing (OTW) Unit

and the loose sun and ring gears in their relative positions is shown by Figure 3.2-1. The internally splined center member shown is the test rig coupling.

Speed and load data based on 100% power and speed are:

Gear pitch line velocity	**97.5 m/s (19,200 ft/min)**
Star gear speed	**10,625 rpm**
Star gear bearing load	**33,171 N (7457 lbs)**
Star gear spherical roller bearing D-N	**0.74×10^6**

Gear data are shown by Table 3-1. Star gear bearing data are shown by Table 3-2.

Design flight operating parameters and experimental engine test cycle including oil flow data are shown by Table 3-3 and Table 3-4. MIL-L-23699 oil with a maximum inlet temperature of 358°K (185°F) was selected for the reduction gear test operation.

TABLE 3-1. UTW REDUCTION GEAR

GEAR DATA

Item	Sun Gear	Star Gear	Ring Gear
No. of Teeth	71	52	175
Pressure Angle, deg.	21	21	21
SI Units			
Module	3.3722	3.3722	3.3722
Pitch Diameter, mm	239.43	175.36	590.14
Center Distance, mm	207.39	-	207.39
Gear Face Width, mm	47.1	51.5	45.9
Backlash, mm	.102 - .152	.102 - .152	.127 - .203
English Units			
Diameteral Pitch	7.5321	7.5321	7.5321
Pitch Diameter, in.	9.4263	6.9038	23.2339
Center Distance, in.	8.165	-	8.165
Gear Face Width, in.	1.856	2.03	1.806
Backlash, in.	.004 - .006	.004 - .006	.005 - .008
Contact Ratio (min) (Max. break edges)	2.01047	-	1.98347
Material	AMS 6265 (SAE 9310)	AMS 6265 (SAE 9310)	AMS 6470

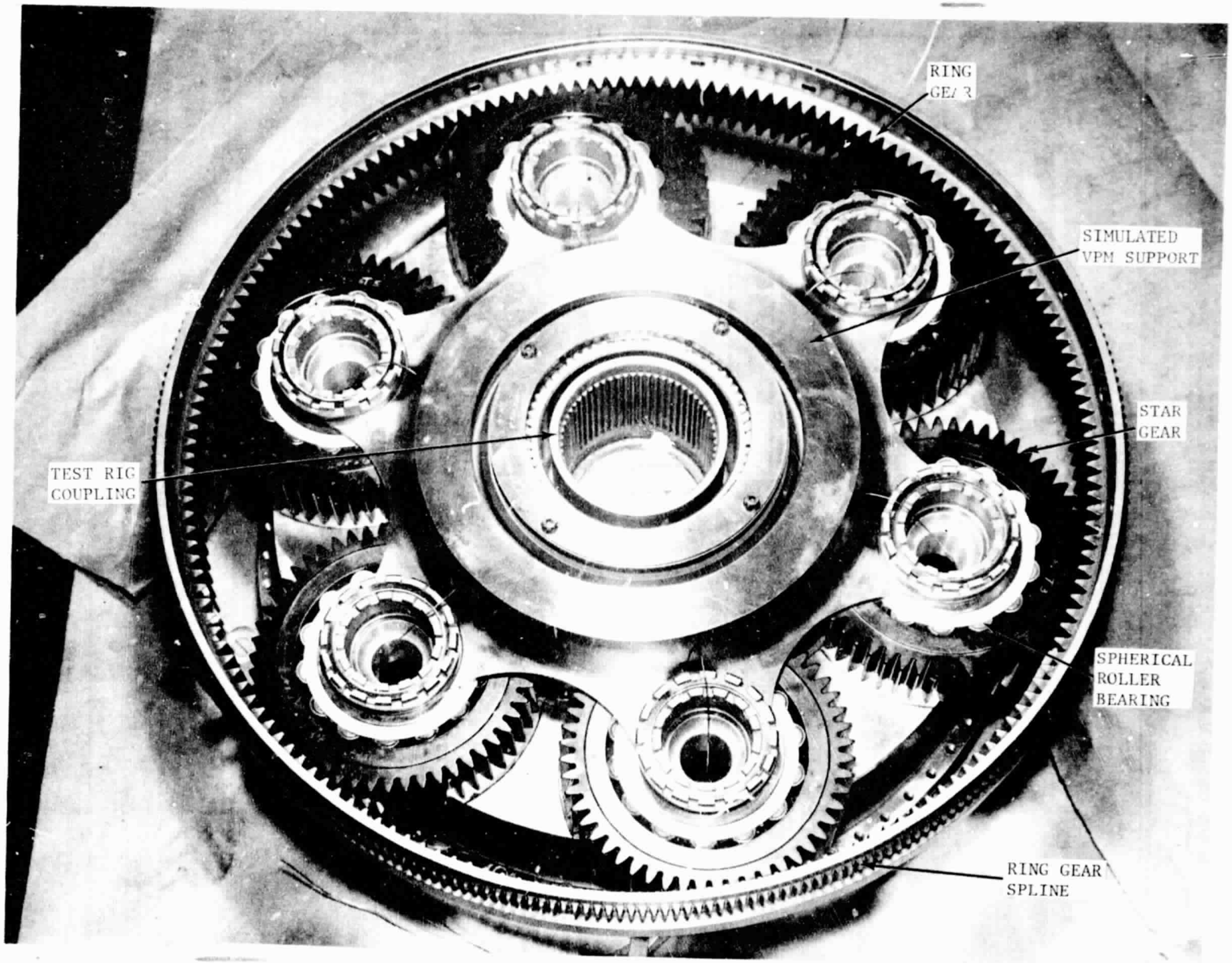


Figure 3.2-1. UTW Unit Reduction Gear

TABLE 3-2. UTW REDUCTION GEAR

BEARING DATA

Vendor, Part No.	SKF 22314 VAH
Type	Double Row Spherical Roller (Special)
No. of Rollers (Per Row)	14
Size of Rollers	20.5 mm x 19.65 mm
Dynamic Capacity, "C"	225,800 N (57,500 Lbs)
Materials:	
Outer Ring (Integral with Gear)	Carburized AMS 6265, Rc 60-63
Inner Ring	CVM M-50 Steel, Rc 60 Min
Rollers	CVM M-50 Steel, Rc 60 Min
Cage	AMS 4616, Silver Plated
Bore Dia., mm	70
Mean Dia., mm	110

TABLE 3-3. UTW REDUCTION GEAR

FLIGHT OPERATING PARAMETERS

Condition	Time %	Power %	Fan Speed Rpm	Oil Flow cm^3/s (GPM)	Oil Pressure N/cm^2 (PSI)
Start	1.11	NIL	-	1356 (21.5)	28 (41)
Idle-Taxi	13.78	0.8	900	1356 (21.5)	28 (41)
Take-Off	2.71	100.0	3157	1451 (23.)	32 (47)
Climb Seg 1	11.11	88.2	3104	1407 (22.3)	30 (44)
Climb Seg 2	11.11	66.0	3340	1369 (21.7)	29 (42)
Cruise	31.11	60.7	3408	1407 (22.3)	30 (44)
Descent	22.22	18.0	1985	1211 (19.2)	23 (34)
Approach	6.67	70.0	3090	1356 (21.5)	28 (41)
Reverse	0.18	50.8	3408	1350 (21.4)	28 (41)

100% Power = 9712 kW (13,019 hp)

TABLE 3-4. UTW REDUCTION GEAR

EXPERIMENTAL ENGINE TEST CYCLE

Time Hrs	Fan Speed Rpm	Power kW (hp)	Oil Pressure N/cm^2 (PSI)
1	3406	9804 (13142)	32 (47)
16	3119	11809 (15830)	31 (45)
15	3157	10973 (14709)	34 (49)
150	3157	9806 (13145)	32 (46)
500	2919	7845 (10516)	30 (44)
1000	2433	4902 (6571)	28 (41)
1000	973	236 (317)	20 (29)

3.3 OTW Unit

The OTW engine reduction gear has a ratio of 2.062:1 and a 100% power and speed rating of 12,615 kW (16,910 hp) at 3860 rpm fan speed. This unit has eight equally spaced star gears. The star gear trunnion length provides for the installation of engine oil tube supports clamped between the bearing nut and the bearing inner race and key slots in the trunnions provide for maintaining alignment of the supports. A photograph of the OTW reduction gears with the loose sun and ring gears in position is shown by Figure 3.3-1. The internally splined center member shown is the test rig coupling.

Speed and load data based on 100% power and speed are:

Gear pitch line velocity	119.2 m/s (23,477 ft/min)
Star gear speed	14,990 rpm
Star gear bearing load	26,432N (5942 lbs)
Star gear spherical roller bearing DN	0.90×10^6

Gear data are shown by Table 3-5. Star gear bearing data are shown by Table 3-6.

TABLE 3-5. OTW REDUCTION GEAR

GEAR DATA

Item	Sun Gear	Star Gear	Ring Gear
No. of Teeth	81	43	167
Pressure Angle, deg.	21	21	21
SI Units			
Module	3.5335	3.5335	3.5335
Pitch Diameter, mm	286.2110	151.9392	590.0895
Center Distance, mm	219.1	-	219.1
Gear Face Width, mm	37.6	42.7	37.6
Backlash, mm	.102 - .152	.102 - .152	.127 - .203
English Units			
Diametral Pitch	7.1884	7.1884	7.1884
Pitch Diameter, in.	11.26815	5.98186	23.23187
Center Distance, in.	8.625	-	8.625
Gear Face Width, in.	1.48	1.68	1.48
Backlash, in.	.004 - .006	.004 - .006	.005 - .008
Contact Ratio (min) (.010 Max. Break Edges)	2.07490	-	2.05664
Material	AMS 6265 (SAE 9310)	AMS 6265 (SAE 9310)	AMS 6470

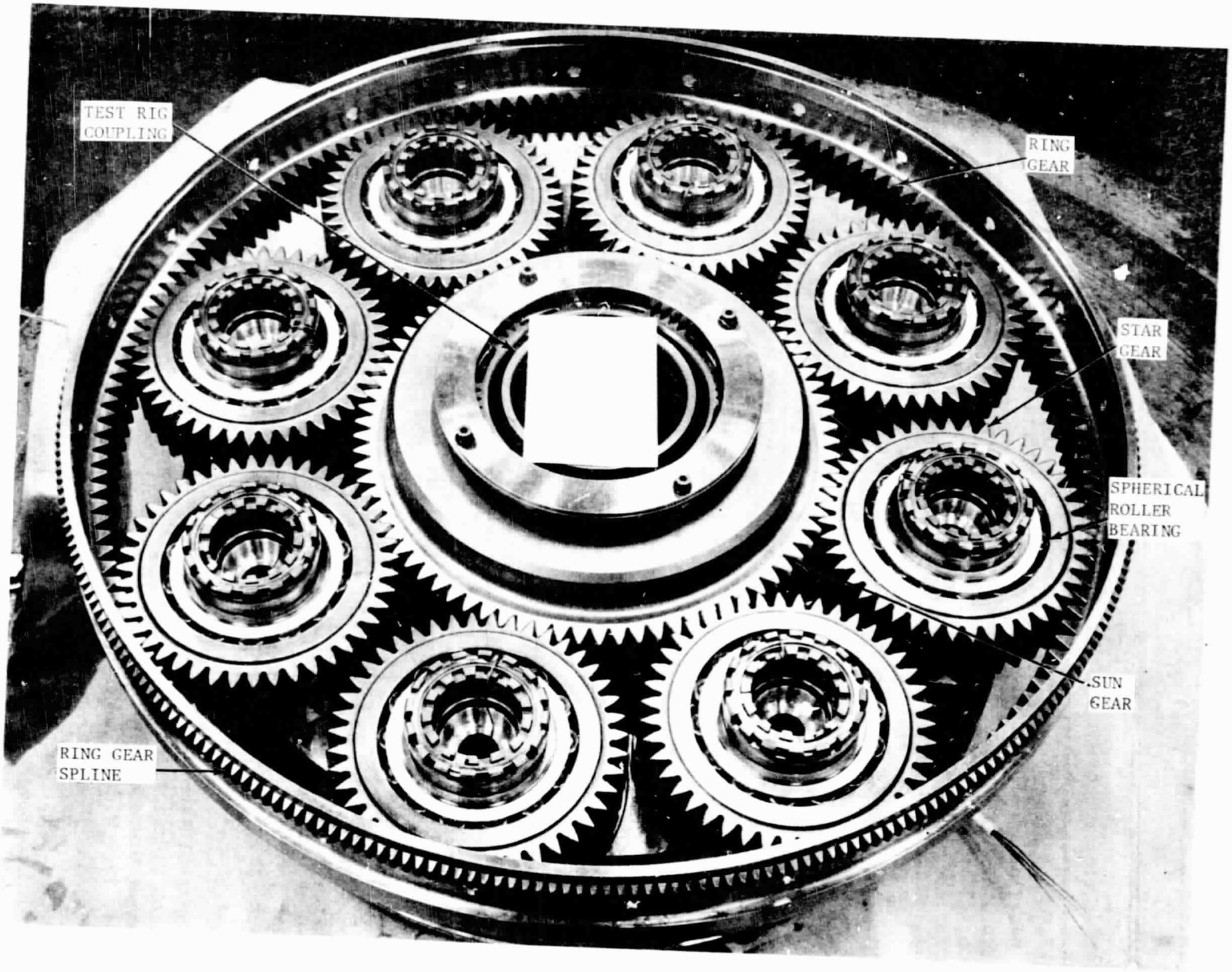


Figure 3.3-1. OTW Unit Reduction Gear

TABLE 3-6. OTW REDUCTION GEAR

BEARING DATA

Vendor, Part No.	SKF 22312 VAM
Type	Double Row Spherical Roller (Special)
No. of Rollers (Per Row)	14
Size of Rollers	18 mm x 17.64 mm
Dynamic Capacity, "C"	202,400 N (45,500 Lbs)
Materials:	
Outer Ring (Integral with Gear)	Carburized AMS 6265, Rc 60-63
Inner Ring	CVM M-50 Steel, Rc 60 Min
Rollers	CVM M-50 Steel, Rc 60 Min
Cage	AMS 4616, Silver Plated
Bore Dia., mm	60
Mean Dia., mm	95.0

Design flight operating parameters and experimental engine test cycle including oil flow data are shown by Table 3-7 and Table 3-8. MIL-L-23699 oil with a maximum inlet temperature of 358°K (185°F) was selected for reduction gear test operation.

TABLE 3-7. OTW REDUCTION GEAR

FLIGHT OPERATING PARAMETERS

Condition	Time %	Power %	Fan Speed Rpm	Oil Flow cm^3/s (GPM)	Oil Pressure N/cm^2 (PSI)
Start	1.11	NIL	-	-	-
Idle-Taxi	13.78	0.8	573	1073 (17)	15 (22)
Take-Off	2.71	100.0	3860	1956 (31)	35 (51)
Climb Seg 1	11.11	88.2	3640	1893 (30)	33 (48)
Climb Seg 2	11.11	66.0	3725	1893 (30)	33 (48)
Cruise	31.11	60.7	3657	1855 (29.4)	31 (45)
Descent	22.22	18.0	2365	1577 (25.)	23 (34)
Approach	6.67	70.0	3104	1754 (27.8)	28 (41)
Reverse	0.18	50.8	3848	1943 (30.8)	34 (50)

100% Power = 12,615 kW (16,910 hp)

TABLE 3-8. OTW REDUCTION GEAR

EXPERIMENTAL ENGINE TEST CYCLE

Time Hrs	Fan Speed Rpm	Power kW (hp)	Oil Pressure N/CM^2 (PSI)
1	3982	12532 (16799)	34 (50)
16	3904	13199 (17693)	36 (52)
15	3848	13015 (17446)	36 (52)
150	3848	12531 (16798)	34 (50)
500	3413	10025 (13438)	32 (47)
1000	2844	6266 (8399)	30 (43)
1000	1137	621 (833)	26 (37)

4.0 APPARATUS AND PROCEDURE

4.1 Test Facility

The test facility consists of an enclosed test cell with an adjacent control room from which the test rig is visible during operation.

The test cell, Figure 4.1-1, includes a raised base with bedplate on which the prime mover, speed increaser and reduction gear test rig are mounted. Also located in the test cell are the test rig lubrication system and the torque loading hydraulic power pack. Water and steam for oil cooling and heating, respectively, and compressed air are provided.

The control room, Figures 4.1-2 and 4.1-3, contains the necessary equipment for controlling speed, torque load, oil pressure and oil temperature and instrumentation for monitoring speed, load, temperatures, oil pressures, oil flows and unit dynamic and acoustic characteristics. The equipment also includes visual and audible warning signals for high temperatures, low oil pressure and metallic chip detection.

4.1.1 Prime Mover

The prime mover is two General Electric Type TLC110 electric dynamometers installed in tandem and operating as a motor. Each unit is rated at 680 amps at 250 volts input with an output of 149 kW (200 hp) and a speed range of 850 to 3000 rpm for a combined rating of 340 kW (455 hp) input and 298 kW (400 hp) output. Power for the dynamometer is provided by a motor-generator unit located in the plant power house. Overload protective circuit breakers are provided in the dynamometer control electrical circuit and at the motor-generator unit.

Each dynamometer unit has separate handwheel type speed controls for both coarse and fine speed adjustment. Instrumentation includes a voltmeter for the motor-generator unit voltage, a voltmeter and ammeter for each dynamometer and a dynamometer speed indicator. The dynamometer drives the test rig through a 3.3:1 ratio speed increaser which has an integral lubrication system.

4.1.2 Lubrication System

The test stand lubrication system consists of an oil reservoir, supply pump, oil pressure controls, 25 micron filter, flowmeters and an oil flow weigh tank. Figure 4.1-4 is a schematic of the lubrication system. The flowmeter arrangement is shown by Figure 4.1-5.

The main oil tank is located on a platform scale. An electrically driven pump delivers the oil from the tank to the system. A relief valve and pneumatically operated pressure control valve are located between the pump and the heat exchanger. A manually operated valve controls the flow of steam to the heat exchanger for heating the oil and a thermostatically controlled temperature regulator controls the flow of water to the heat exchanger for oil cooling. A bypass line with a manually operated valve is provided between

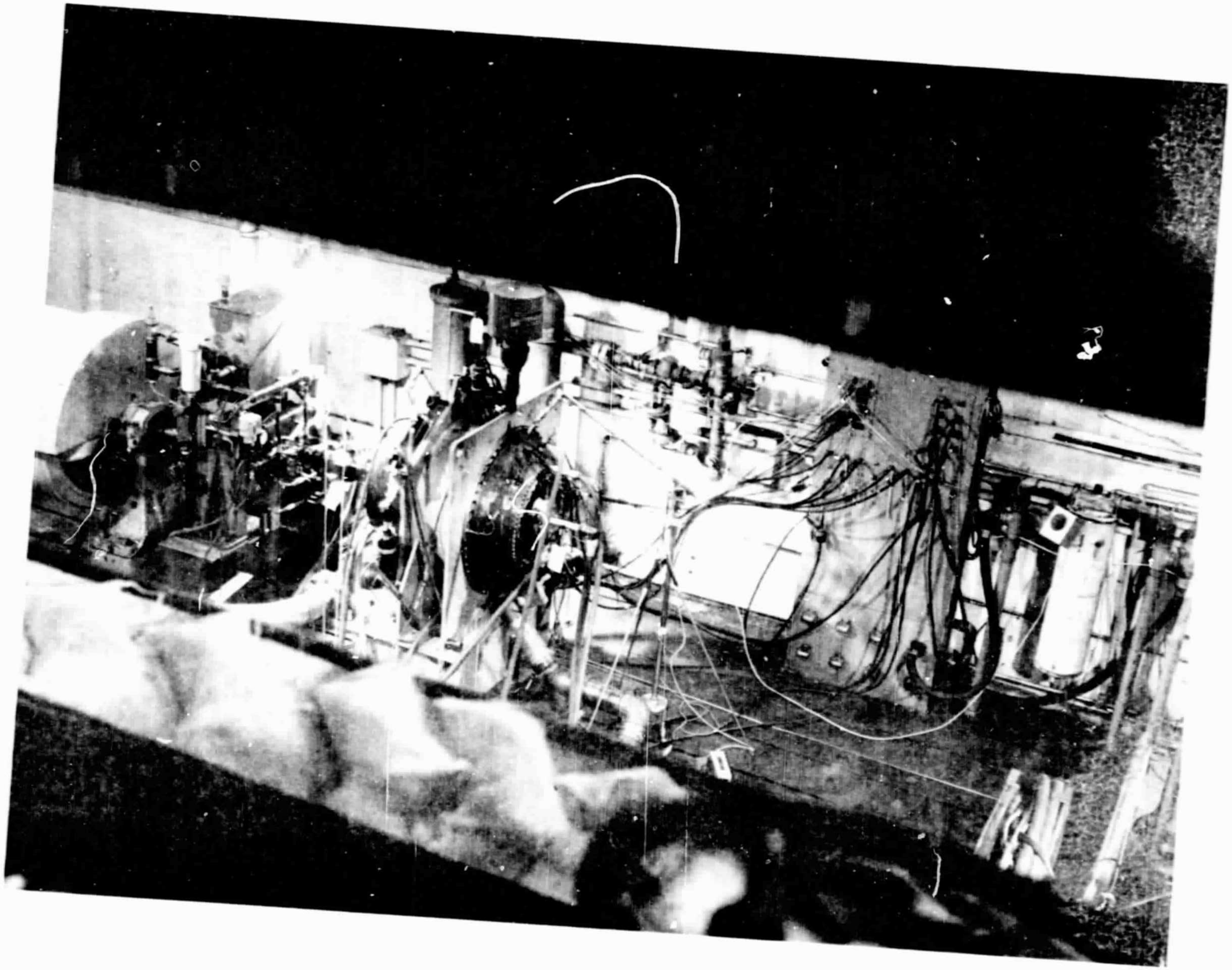


Figure 4.1-1. QCSEE Main Reduction Gears Test Facility

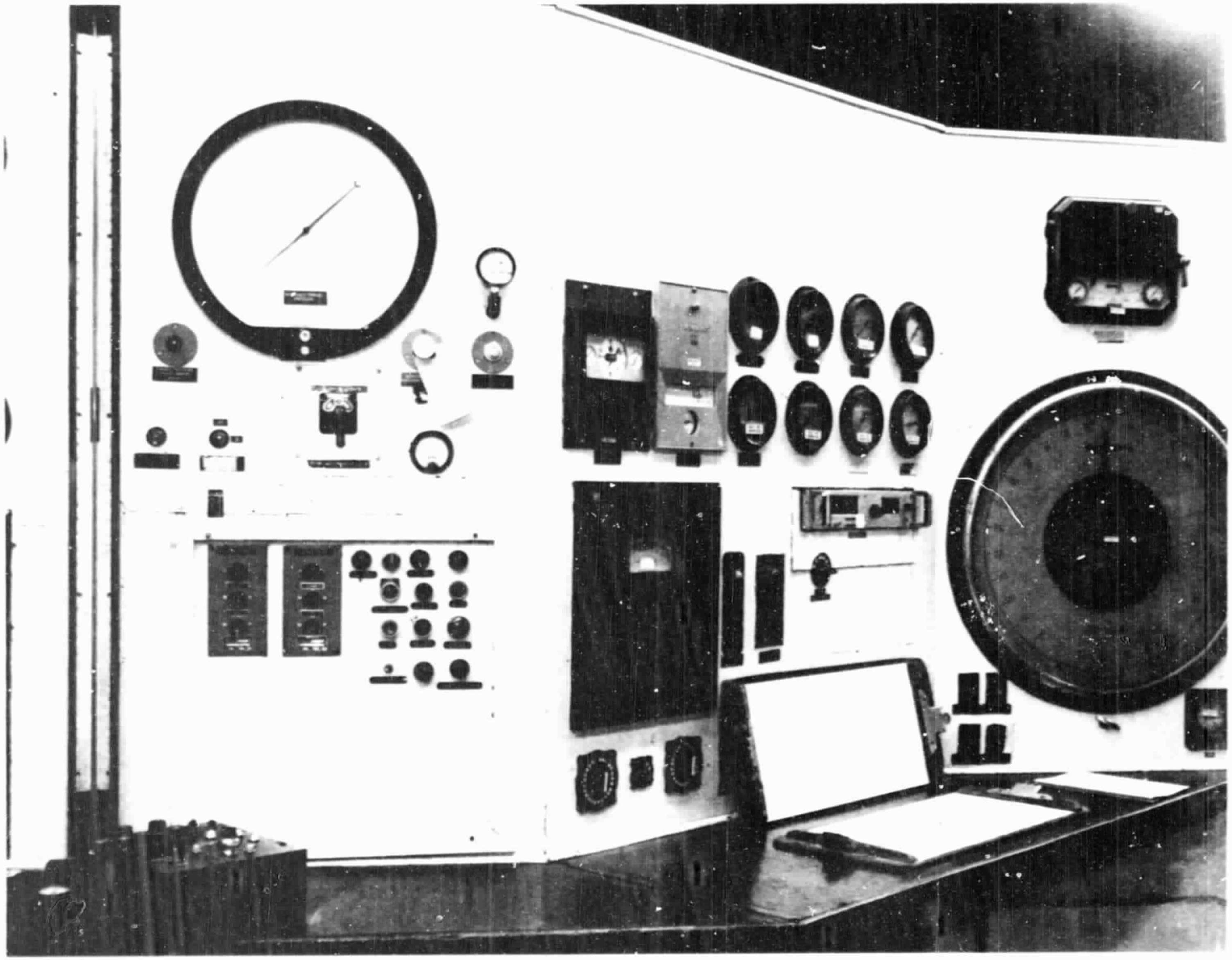


Figure 4.1-3. QCSEE Main Reduction Gears Test Facility Control Panel

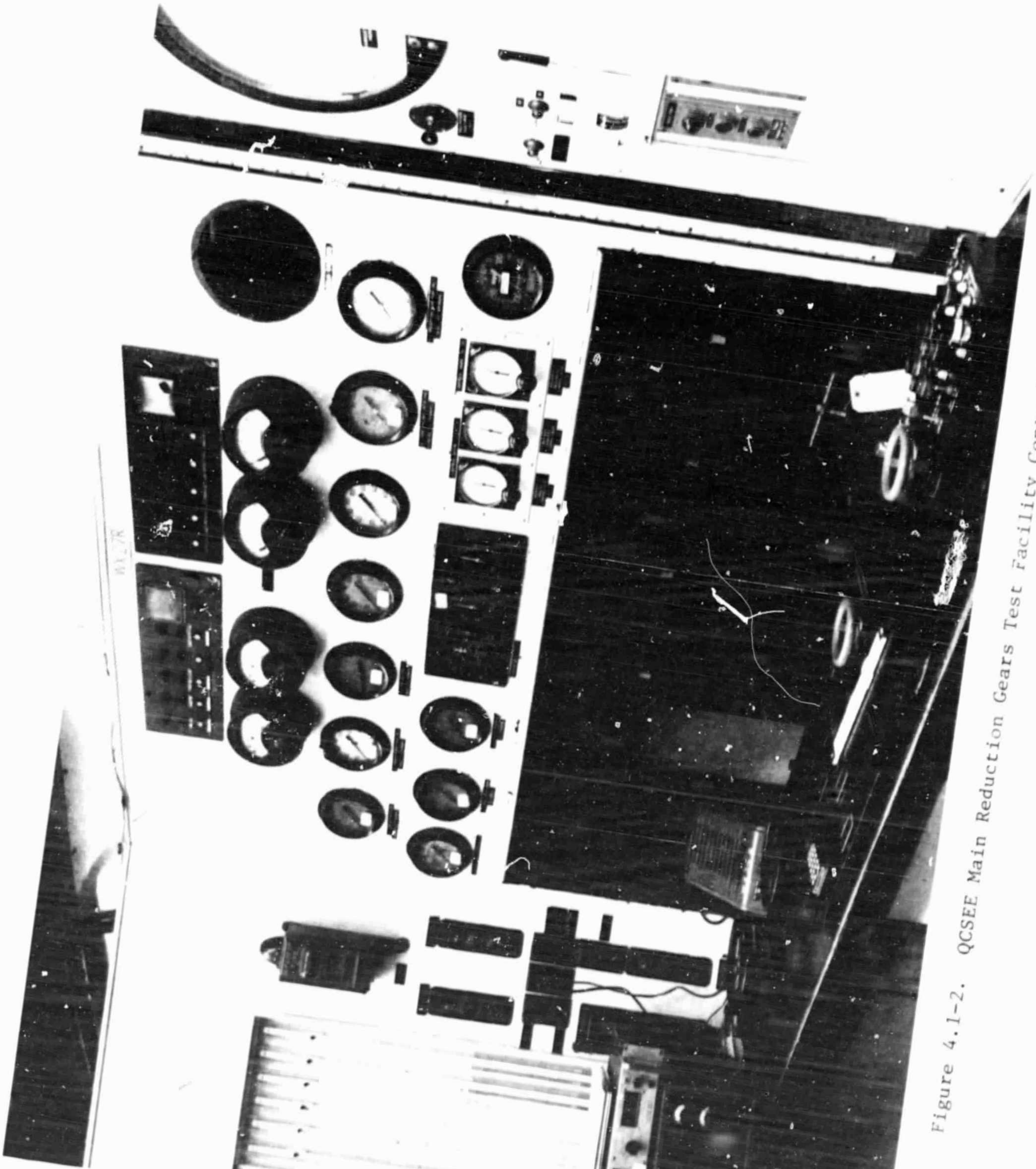


Figure 4.1-2. QCSEE Main Reduction Gears Test Facility Control Panel

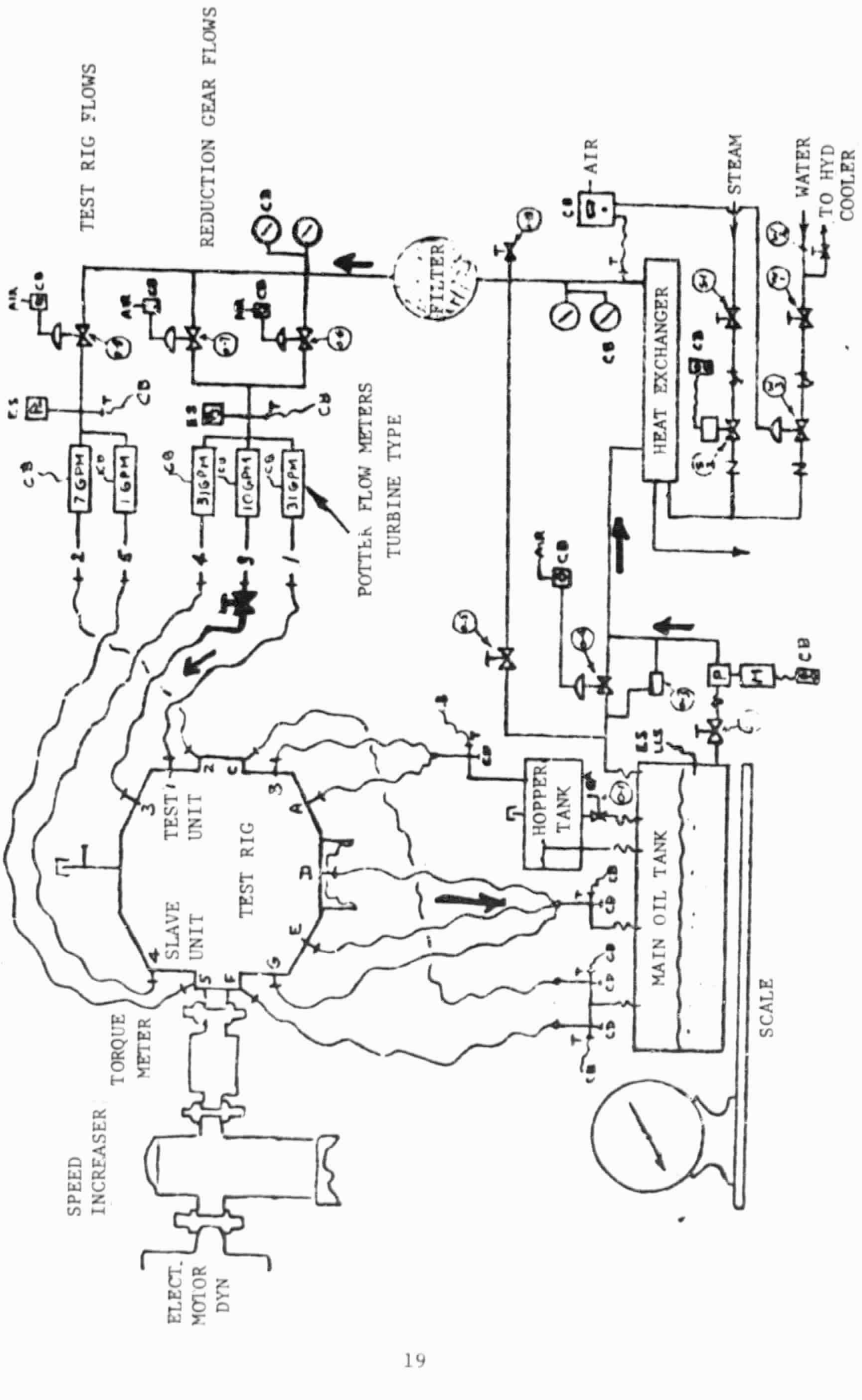
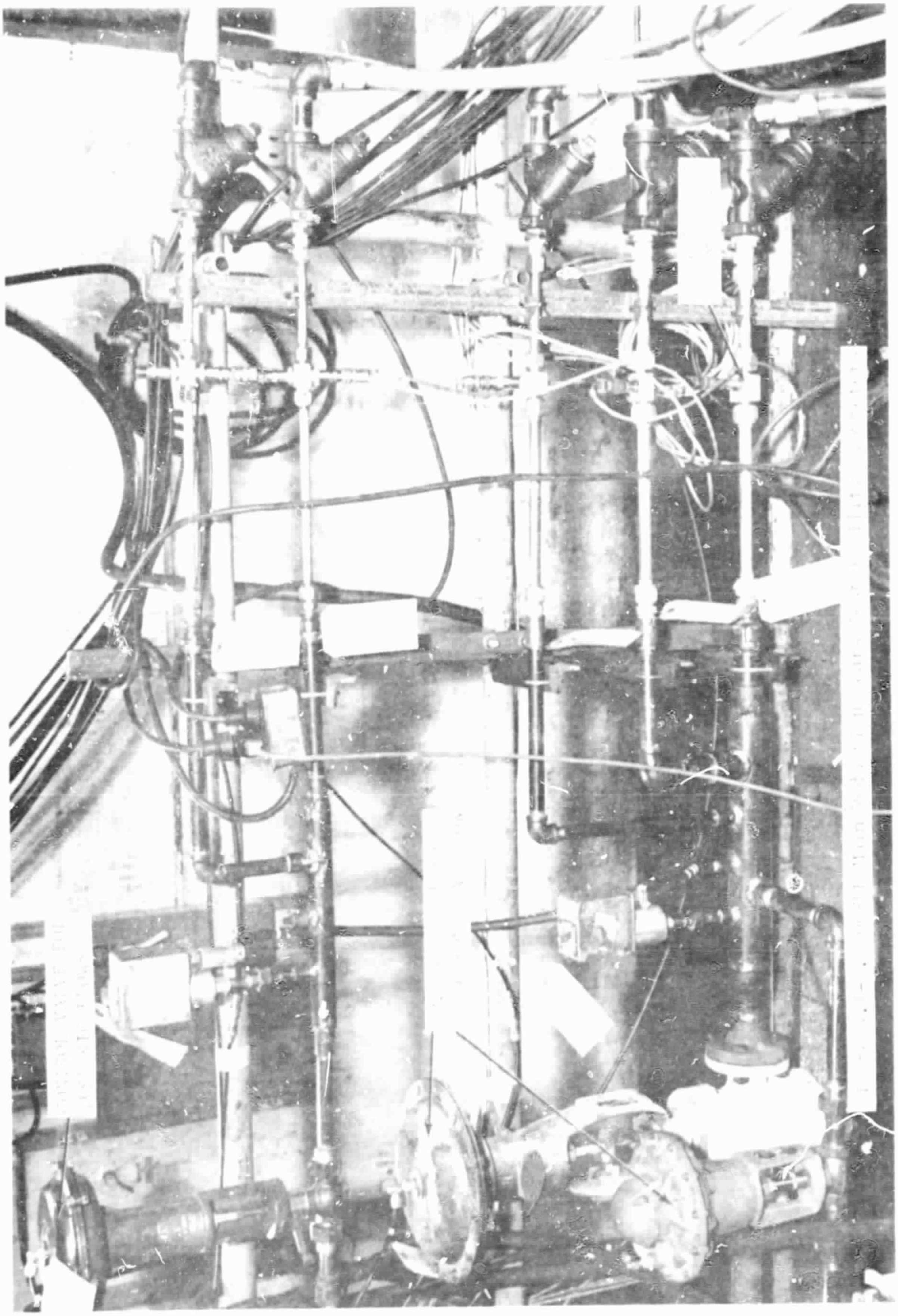


Figure 4.1-4. Test Rig Oil Schematic



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the heat exchanger and the filter for recirculating the oil back to the tank for prestart heating.

All oil to the test rig passes through a 25 micron filter at constant temperature and then is divided into two branches of the system. One branch supplies the oil to the reduction gears and the other to the test rig bearings. Pneumatically operated pressure controllers provide independent control of the oil pressure in the two branch systems, two for the reduction gears and one for the test rig bearings.

The reduction gear branch provides flow at constant pressure to each of the two reduction gear units and to a third line into the rig housing on the test end of the rig to simulate the return oil flow from fan shaft bearing lubrication in the engine. The latter has a manual shut-off valve. The oil pressure in the reduction gear flow can be adjusted from the control room to simulate the engine oil supply for the particular speed/load operating condition.

The test rig branch is divided for flow to each end of the test rig for rig bearing lubrication. Each of the five oil lines contains a turbine type flowmeter.

The oil return lines from the test unit end of the test rig (A & B of Figure 4.1-4) go to a hopper or holding tank which has a manually operated drain valve for checking the return flow rate from the reduction gear. When the valve is open, the oil drains directly from the holding tank into the main oil tank. Oil from the other drains on the rig return directly to the main oil tank.

UTW unit test operation was conducted with Specification MIL-L-23699 oil supplied by Royal Lubricants. Initial OTW unit test operation used Aeroshell Turbine Oil 555 but subsequently MIL-L-23699 oil was used. The two lubricants are similar but the Aeroshell 555 is reported to have a higher Ryder Gear Test rating than MIL-L-23699. Following is a brief comparison of the two oils; viscosity and specific gravity are actual checks, Ryder Rear Test Rating is from vendor:

Characteristic	MIL-L-23699 Specification	MIL-L-23699 Royal Lubricants	Aeroshell Turbine 555
Viscosity @ 210°F, cs.	5.00-5.50	5.2	5.2
Specific gravity	-	.951	.941
Ryder Gear Test Rating, lb/in	2142-2652 min.	3000	>3000

4.1.3 Torque Loading Hydraulic System

The torque load is introduced into the gear system by six hydraulic rams attached to the test rig. A hydraulic power pack, Figure 4.1-6, provides the hydraulic pressure for actuating the torque loading rams. The unit pressure control is adjustable from the test facility control room to provide and maintain any pressure level setting required to simulate engine torque loads in the reduction gears being tested.

4.2 Test Rig

The test rig is a Hopkinson type back-to-back unit wherein two identical ratio reduction gears are torque loaded against each other and the driving effort is only that power required to overcome internal losses. A cross-section of the rig with UTW reduction gear units is shown by Figure 4.2-1. The rig housing consists of two sections; one is stationary and the other, attached to the stationary one through a large diameter thin section four point contact ball radial bearing, is rotatable through a limited angle by six hydraulic rams shown in the drive end view of the test rig, Figure 4.2-2.

The gear unit stationary star gear supports are attached to the rig housing sections. The input shaft is supported in the rig housings by a ball bearing at one end and a cylindrical roller bearing at the other end. The connecting shafts for the ring gears are supported on the input shaft by a pair of wave spring axial pre-loaded face-to-face mounted angular contact ball bearings. The ring gear connecting shafts and the ring gear retaining shrouds simulate the General Electric engine fan shaft configuration. Also attached to the input shaft through splines are two diaphragm type couplings for attachment of the two similar type gear unit couplings which support the sun gears. Thus, with the star gears on the stationary support trunnions the gear meshes form a closed loop. Application of pressure to the torque loading hydraulic rams and rotating the drive end section of the rig housing and attached star gear support relative to the stationary section of the housing and attached star gear support, introduces torque loading into the gear system. In this arrangement one unit functions as a speed reducer and the other as a speed increaser.

The input shaft rotation viewed from the drive end is counterclockwise for this test rig. The torque loading direction induced by extending the hydraulic rams is such that the gear unit in the rig drive end housing operates as a speed increaser and the gear unit in the stationary housing operates as the speed reducer. The latter is the test unit.

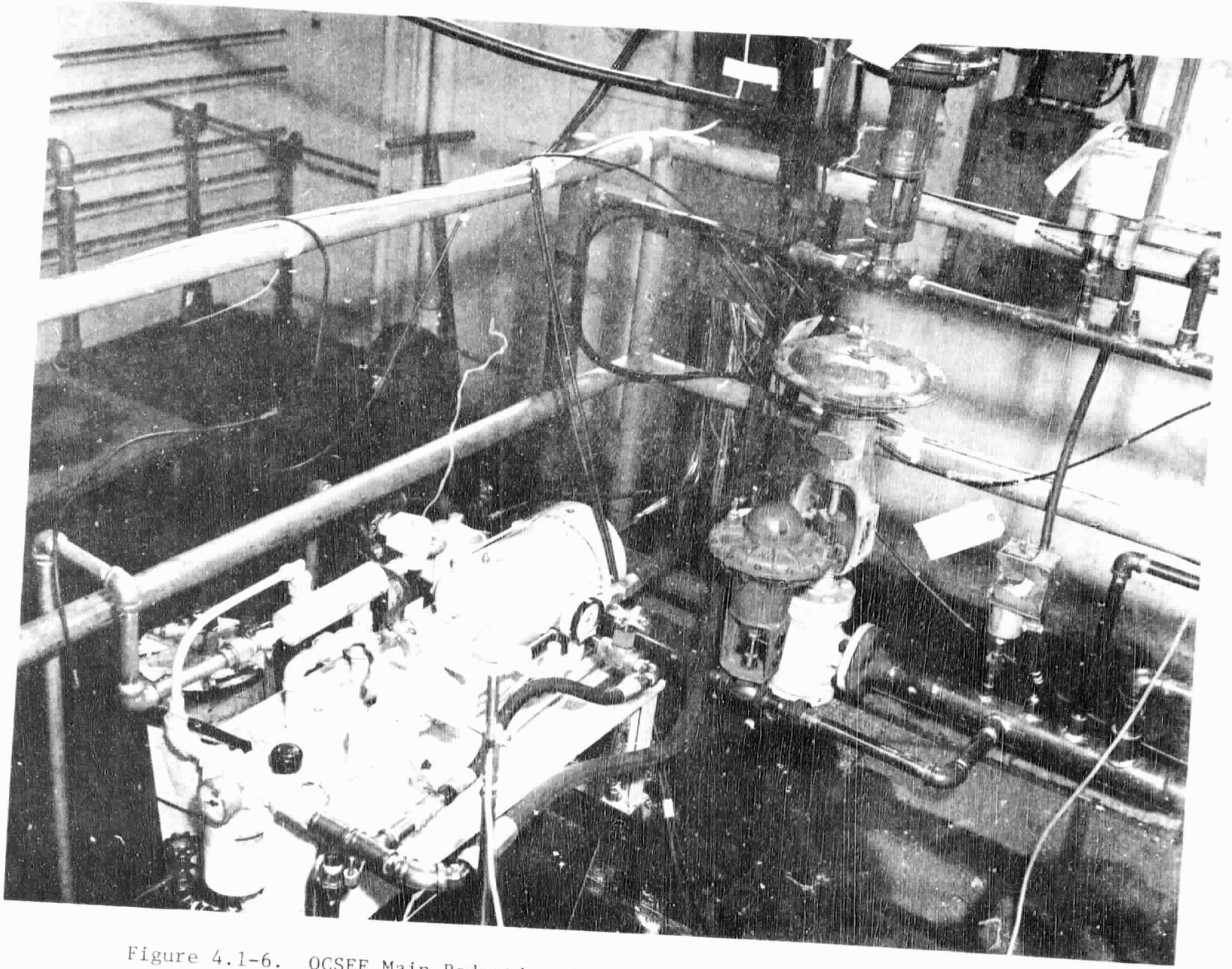

Figure 4.1-6. QCSEE Main Reduction Gears Test Facility Hydraulic Power Pack

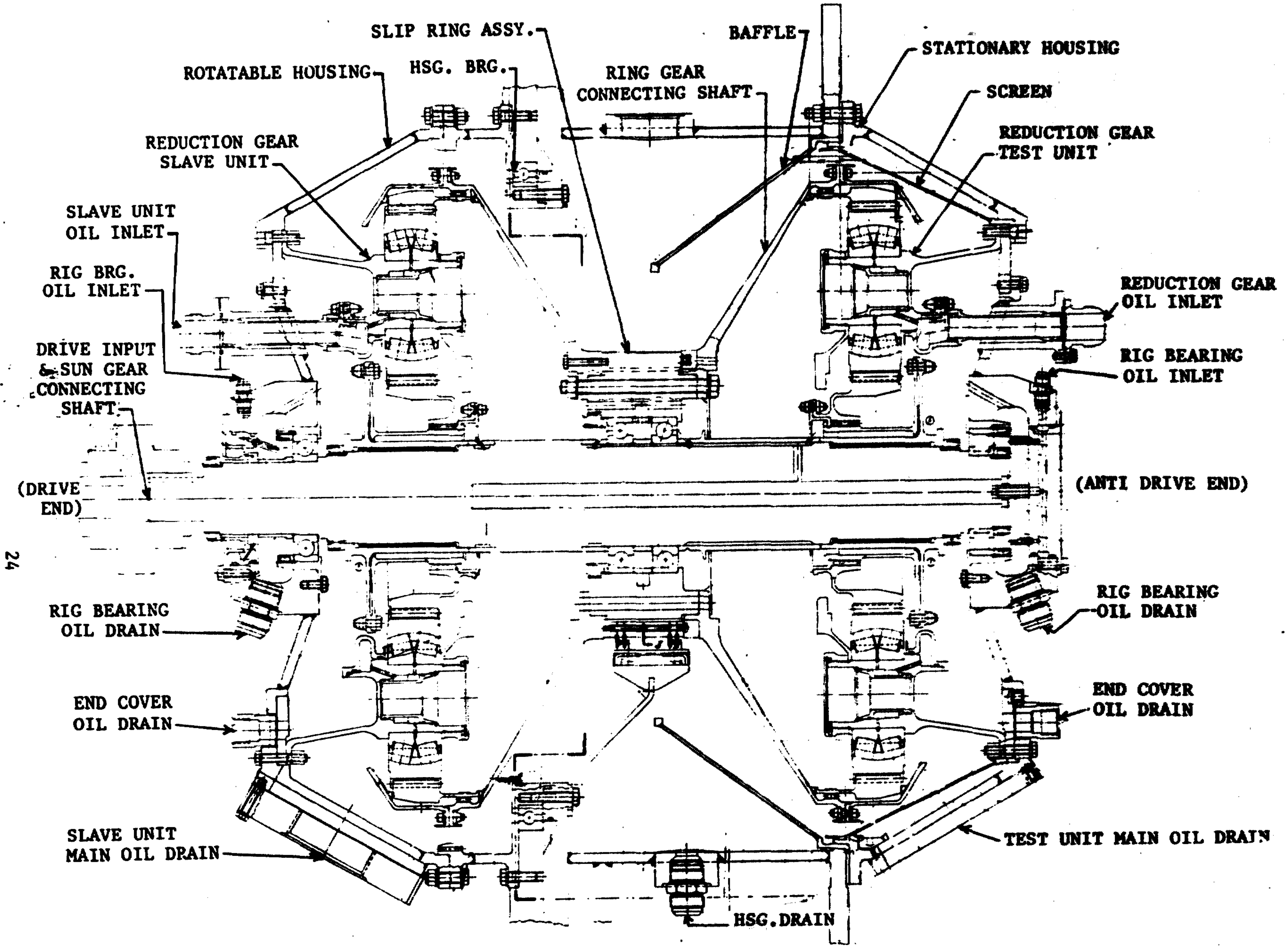

Figure 4.2-1a QCSEE Main Reduction Gear Back-to-Back (Hopkinson) Test Rig (Section View)

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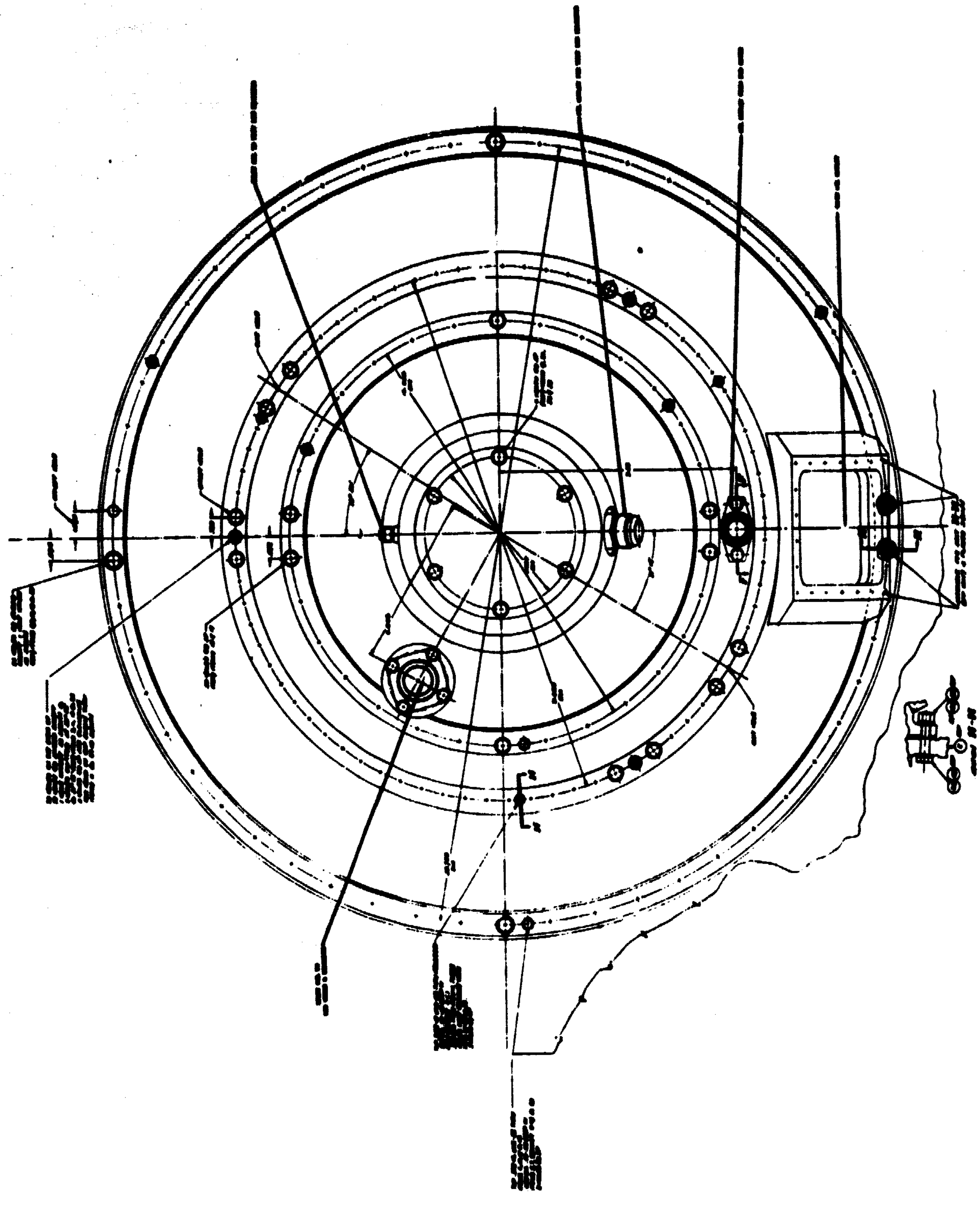


Figure 4.2-1b QCSEE Main Reduction Gear Back to Back (Hopkinson) Test Rig (View From Test Unit (Anti-Drive) End)

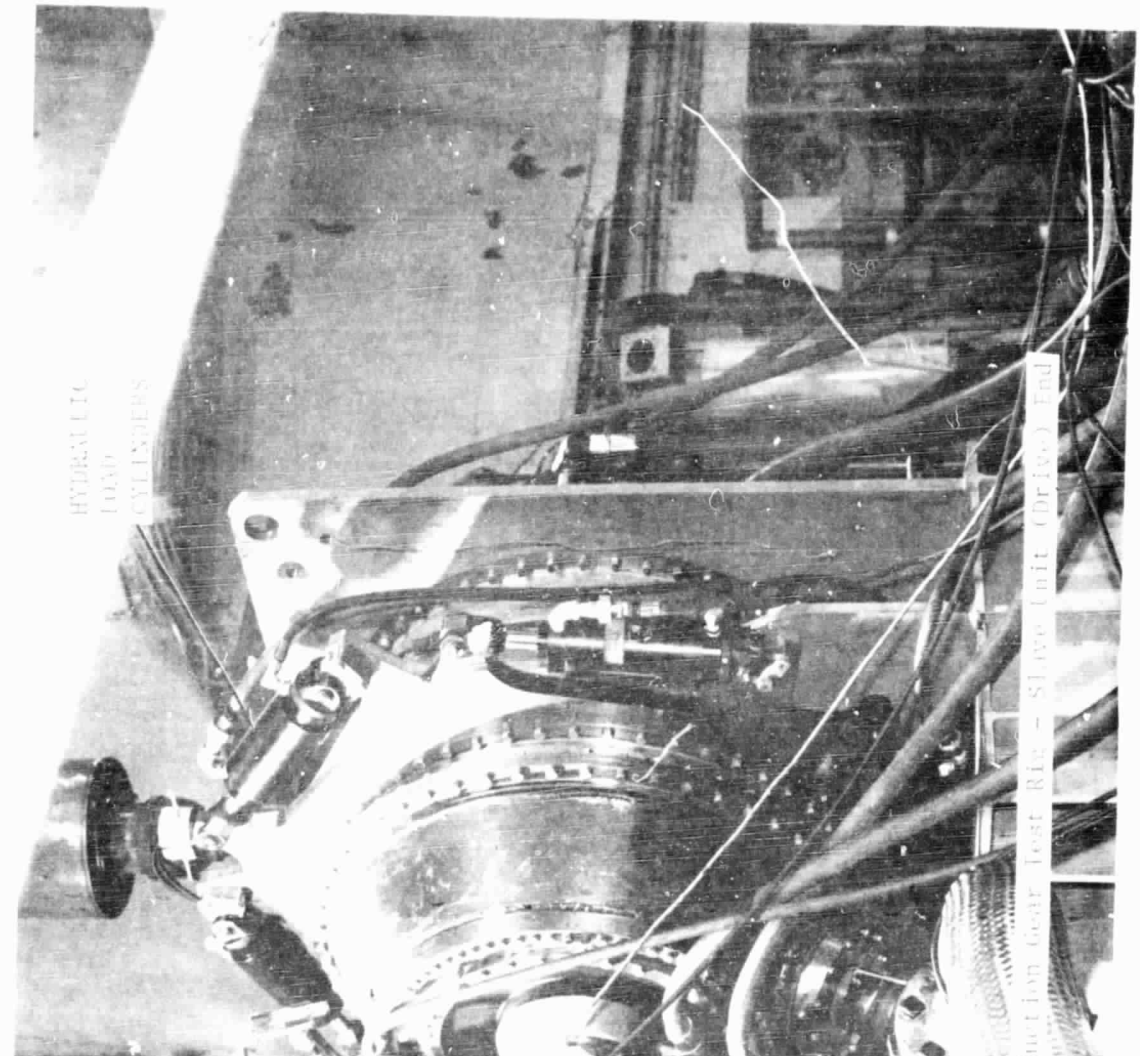


Figure 4.2-2. QCSEE Main Reduction Gear Test Rig - Slave Unit (Drive) End

The test unit is loaded and rotates in the same direction as in the engine installation. Although the gear tooth loading is in the same relative direction for both units, the speed increaser or slave unit rotates in the opposite direction relative to that in the engine installation.

A conical baffle and a screen shown in the test unit end of the rig in Figure 4.2-1 were included to further simulate the walls in the engine reduction gear housing. The screen shown was replaced by an engine part, G.E. P/N 4013101-852G02, and a screen support, G.E. P/N 4013101-907P01 at the time of rig fabrication.

Provision was made for installing a slip ring assembly around the center member of the ring gear connecting shaft for transferring signals from strain gages installed on the test unit ring gear.

An adapter which mates with the gear unit oil supply tube is provided in the cover on each end of the test rig for delivering oil to the gear units. The test unit oil connection is shown in Figure 4.2-3. An additional connection, Figure 4.2-4 was incorporated in the top of the housing on the test unit end of the rig to introduce oil simulating engine shaft bearing oil which is discharged into the gear cavity for scavenging.

The rig bearings are lubricated through a connection on each of the end covers. The input shaft supporting ball and roller bearings are each lubricated by two jets. The bearings between the ring gear connecting shaft and the input shaft and the sun gear to coupling splines are lubricated by jets fed from a drilled passage down the center of the input shaft from the test unit (anti-drive) end. This passage is filled by excess oil flow from a jet on the cover on the test unit (anti-drive) end of the rig, the same oil source that supplies the oil to the cylindrical roller bearing. A baffle on the reduction gear test unit side of the intershaft bearing isolates bearing oil flow from the test unit cavity. Oil from the bearings drains through radial and axial passages in the ring gear connecting shaft center member into the slave unit oil cavity.

Scavenging of the test rig is by gravity. The major drains are in the end housings directly beneath the gear units. An additional drain for oil collecting inside the star gear support is located in each of the end cover pilot rings. In the test unit end of the rig the latter drain is joined to the main drain and feeds into the lubrication system holding tank for checking oil flow distribution within the rig. Drains are also provided in each of the end covers for the rig input shaft bearing cavities. A drain located in the center of the main housing takes care of any oil spillover from the end housings. Additional drains and drain modifications incorporated during the course of the testing are discussed in the test section of this report. A drain adapter tube, G.E. P/N 4013179-783G01, which simulated the engine strut drain area was provided by General Electric and installed on the main drain from the test unit end of the rig. This part is seen in Figure 4.2-3. All drains except as noted above return to the lubrication system main oil tank. The test rig is vented by a breather filter located in the top near the center of the main housing.

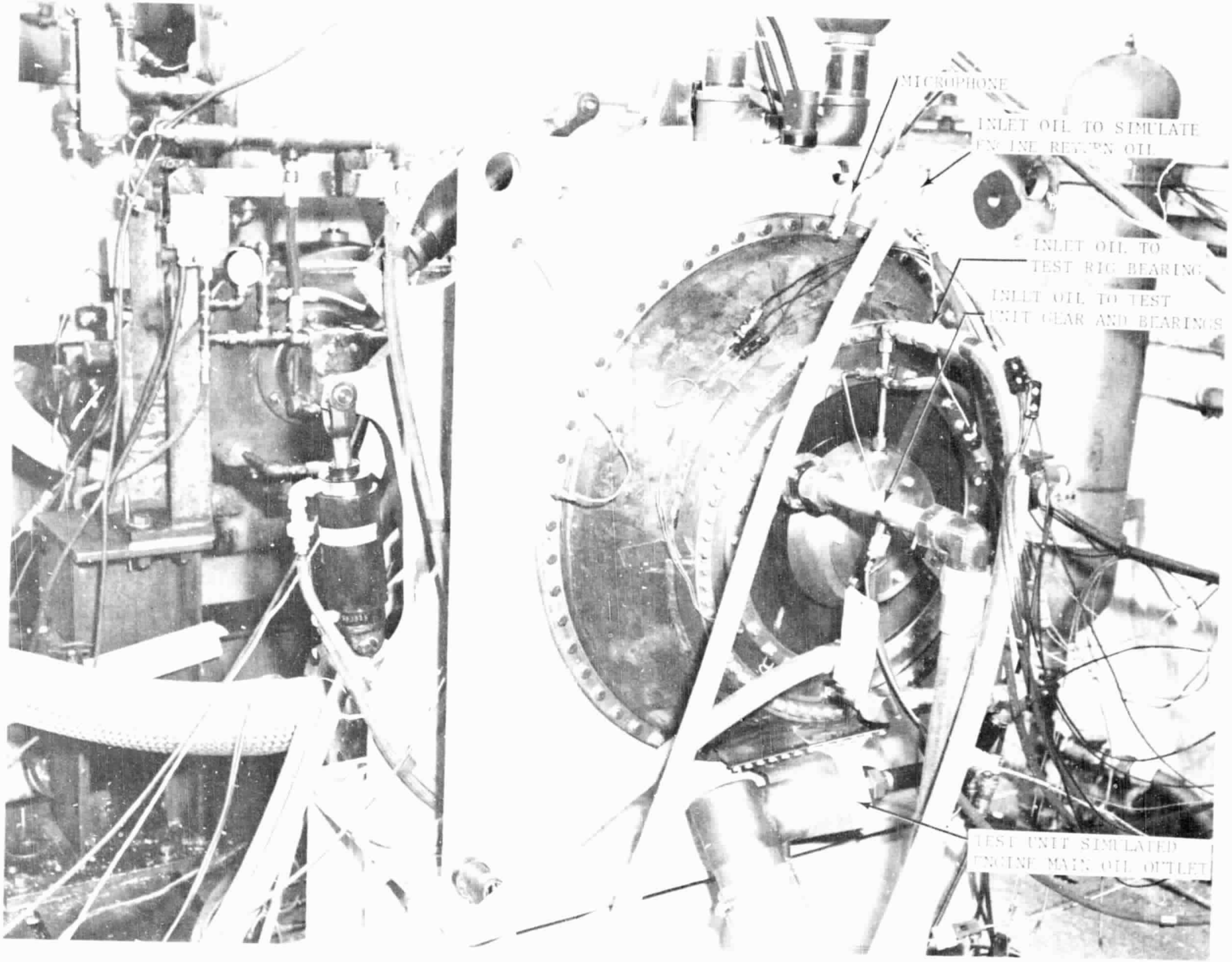


Figure 4.2-3. QCSEE Main Reduction Gear Test Rig - Test Unit End

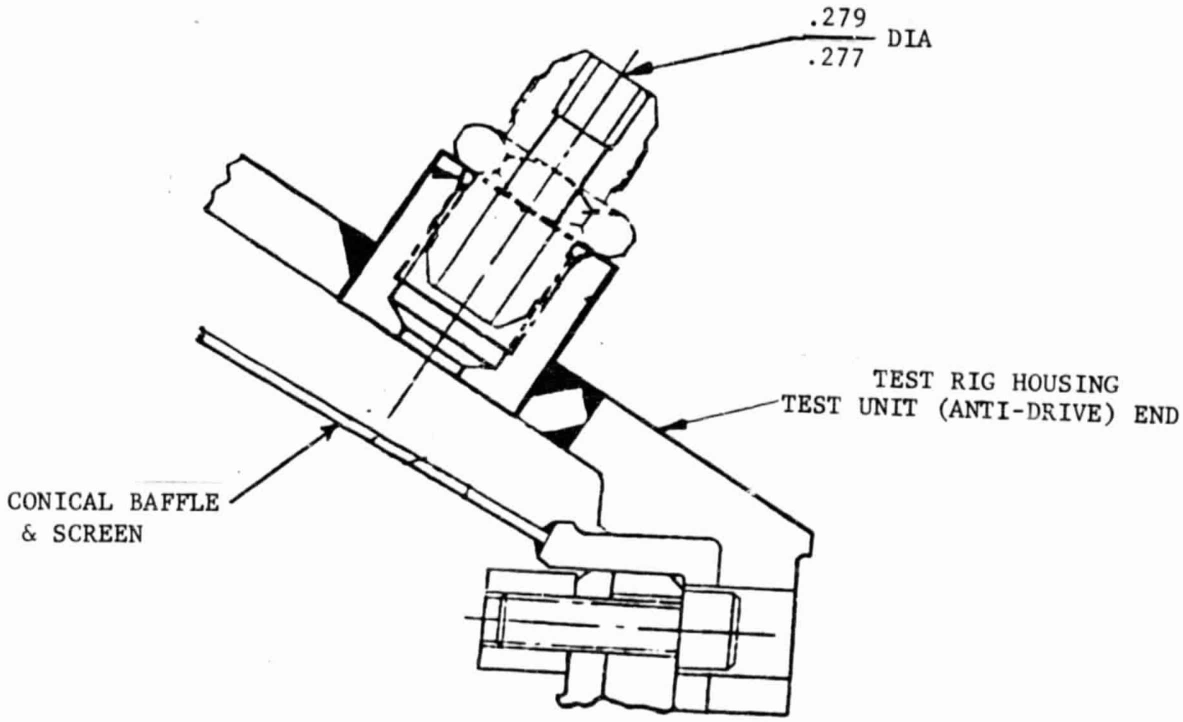


Figure 4.2-4 QCSEE Main Reduction Gear Test Rig Auxiliary Oil Connection to Simulate Engine Return Oil.

Assembly of the test rig is covered by QCSEE Main Reduction Gear assembly procedure QCSEE A-3, UTW Unit Test Rig, which is included in the Appendix.

4.3 UTW Test Hardware

UTW test hardware included two complete sets of reduction gear hardware as described in Sections 3.1 and 3.2 and shown by Figure 3.1-1 in this report with exceptions as listed below. Reduction gear assembly is covered in the QCSEE Main Reduction Gear assembly procedures QCSEE A-1 UTW Star Gear and Support Subassembly, QCSEE A-2 UTW Sun Gear Subassembly, and QCSEE A-3 UTW Unit Test Rig which are included in the Appendix.

Oil sleeve P/N 185147 was used in all six star gear support trunnions, two replacing two P/N 185179 which were not required for fan shaft thrust bearing lubrication.

Special spray tubes, P/N ES164354, identical to P/N 185144 except with the angular direction of the jets reversed, were used on the slave unit because of direction of rotation being opposite that of the test unit and the unit as installed in the engine.

A simulated variable pitch mechanism support, P/N 185150 was installed on the star gear support trunnions to duplicate trunnion deflection restraint conditions existing in the engine. Bearing temperature thermocouples were also incorporated in this support.

Two covers with gaskets were used to close openings in the back of P/N 490640 oil manifold which were provided for the engine fan shaft rear bearing lubrication connections.

4.4 OTW Test Hardware

OTW test hardware included two complete sets of reduction gear hardware as described in Sections 3.1 and 3.3 and shown by Figure 3.1-2 in this report with exceptions as listed below.

Oil sleeve P/N 185161 was used in all eight star gear support trunnions, two replacing two P/N 185225 which were not required for fan shaft thrust bearing lubrication.

Special spray tubes, P/N SK030876, identical to P/N 185144 except with the angular direction of the jets reversed, were used on the slave unit because of direction of rotation being opposite that of the test unit and the unit as installed in the engine.

Flat washers with bearing temperature thermocouples incorporated were installed in place of the G.E. oil tube support on each star gear trunnion.

Two covers with gaskets were used to close openings in the back of P/N 490647 oil manifold which were provided for the engine fan shaft rear bearing lubrication connections.

4.5 Instrumentation

Test rig instrumentation included oil temperatures, bearing temperatures, oil pressures, oil flows, torque loading hydraulic pressure, dynamometer speed, test rig input speed, rig driving torque, vibration, ring gear dynamic strain gauges, and two microphones.

Temperatures were read from a continuous balance precision indicating potentiometer pyrometer which included selector switches for the individual thermocouples. A similar recording type unit was used for selected oil and bearing temperatures to observe transient temperatures and stabilized temperature points during and following speed and/or load changes.

The temperature of oil flowing to the test rig was automatically maintained by an adjustable temperature controller located in the test facility control panel. This instrument regulated the flow of water or steam through the heat exchanger to achieve the set desired temperature.

A thermocouple was installed in each oil inlet to the test rig. These locations were:

a. Test gear unit oil supply
b. Rig bearings - Test (anti-drive) end
c. Auxiliary oil supply
d. Slave gear unit oil supply
e. Rig bearings - Slave (drive) end

The temperature of oil leaving the rig was determined with thermocouples at each of the following locations:

a. Test gear unit main drain
b. Test gear unit end cover pilot ring drain
c. Slave gear unit main drain
d. Slave gear unit end cover pilot ring drain
e. Test rig housing center drain
f. Rig bearing cavity drain - Test (anti-drive) end
g. Rig bearing cavity drain - Slave (drive) end

The bearing inner race temperatues were monitored by thermocouples installed in the simulated variable pitch mechanism support or in individual washers clamped between the bearing and the bearing nut. The tips of the thermocouples were in contact with the forward face of the bearing race. These thermocouples were located on the radial line between the center of the sun gear and the star gear.

Oil pressures were indicated by dial gauges located in the test facility control panel and connected to the following oil inlet locations on the test rig.

a. Test gear unit oil supply
b. Rig bearing oil supply - Test (anti-drive) end
c. Auxiliary oil supply
d. Slave gear unit oil supply
e. Rig bearing oil supply - Slave (drive) end

Oil flows were measured by turbine type flowmeters with the frequency indicated by a digital preset frequency counter. A calibration chart for each flowmeter was used to convert the observed frequencies to actual oil flows. The flowmeters are shown in Figure 4.1-5.

The hydraulic pressure on the torque loading hydraulic cylinders was indicated by a pressure gauge with 0 - 1500 psi range and the dial graduated in 1 psi increments. The pressure gauge mounted on the control panel is seen in Figure 4.1-3.

The dynamometer speed was shown by a tachometer activated by a signal generator on the end of the dynamometer shaft. A revolution counter operating from the same signal generator was used for a more precise speed check.

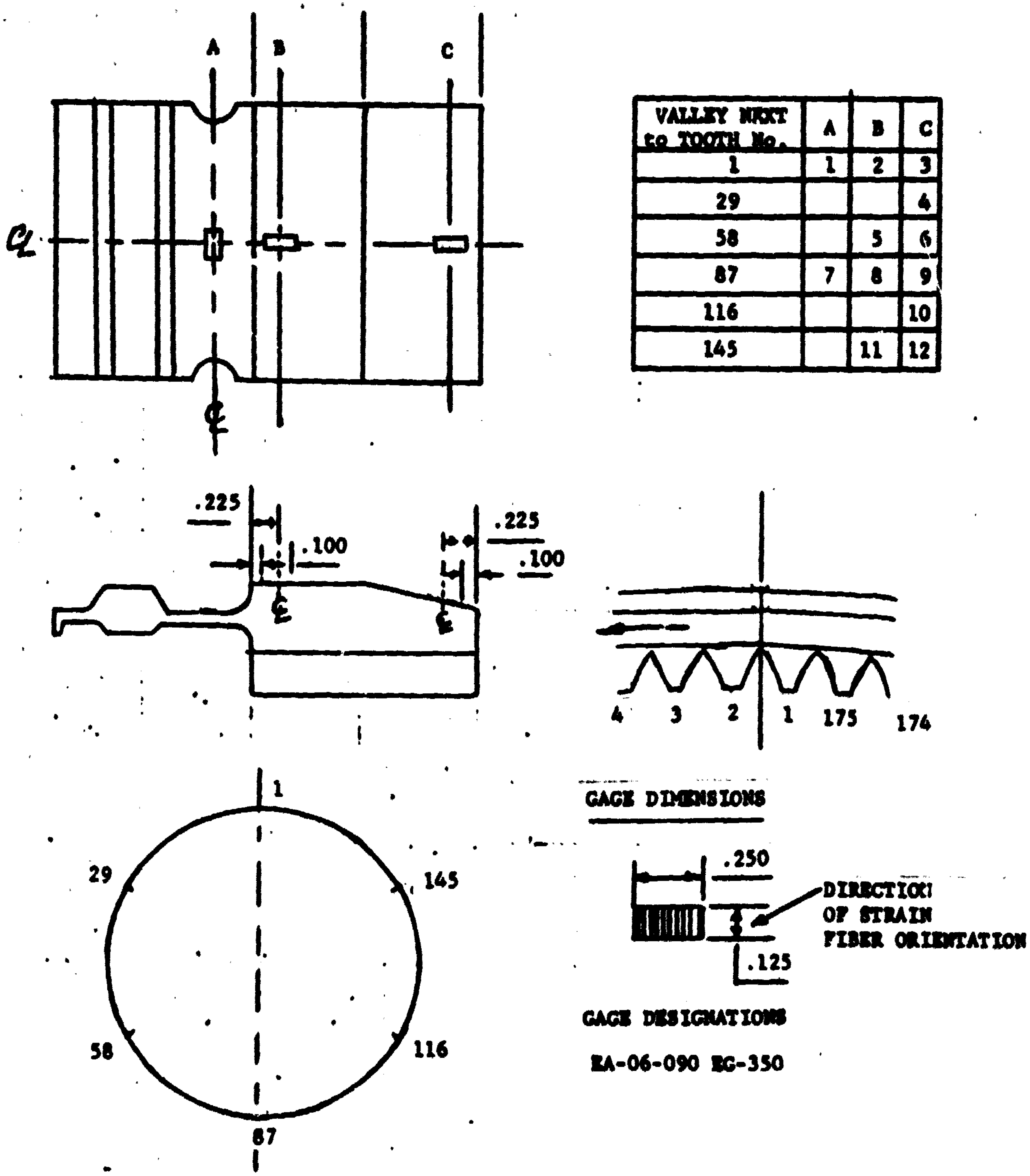
A Lebow torquemeter in the drive line between the test facility speed increaser and the test rig was sued to measure the rig driving torque. In addition to providing an indication of the power losses in the gear units in the test rig, the torquemeter provides the earliest indication of any change in the operating performance of the gearing being tested. The torquemeter also included a speed signal pickup which was fed into a digital preset counter for direct reading of the test rig input speed.

The input power voltage and amperage for each dynamometer was indicated by instruments in the control panel. The ammeters have a range of 800 - 0 - 1500 amperes with scale graduations of 50 amperes and the voltmeters have a range of 0 - 500 volts with scale graduations of 10 volts.

The UTW test unit ring gear was instrumented with strain gages to check ring gear resonance and stress during step-load test operation. A total of 12 strain gages were installed on the outside of the rim and web sections in locations as follows and further defined by Figure 4.5-1.

Six approximately equally spaced gages were located on the tapered end of the ring gear section. Four gages were located on the heavier end of the ring gear section at approximately 0°, 60°, 180° and 240° axially in line with gages on the tapered section. Each of the rim gages was located in line with the gear tooth space or thinnest section of the rim. Two gages were installed on the thin section connecting the gear and the spline approximately 180° apart and axially in alignment with pairs of gages on the gear rim.

The strain gage signals were transmitted from the rotating gear through a slipring assembly, mounted on the hub connecting the ring gear support shafts, and stationary contact fingers. The slipring installation is shown in Figure 4.2-1a. The strain gage signals were recorded on magnetic tape for subsequent analysis.



VALLEY NEXT to TOOTH No.	A	B	C
1	1	2	3
29			4
58		5	6
87	7	8	9
116			10
145		11	12

Figure 4 5-1 QCSEE Main Reduction Gear Ring Gear Strain Gage Instrumentation

A condenser type microphone, Altec Model 165A, placed on the rig centerline near the upper part of each end cover was used to audibly monitor test operation. The output from the microphone at the test unit end of the rig, Figure 4.2-3, was recorded for possible sound and vibration analysis and correlation with other vibration pickup instrumentation.

Vibration pickups were installed on the dynamometer, facility speed increaser and at several points on the rig test rig. Locations on the test rig were as follows:

Direction	Location	Mounting
Vertical	Slave (Drive) end	Bracket on star gear support bolt circle
Horizontal	Slave (Drive) end	
Fore/Aft	Slave (Drive) end	
Vertical	Test (Anti-drive) end	Center top of housing flange plate
Horizontal	Test (Anti-drive) end	Bracket on star gear support bolt circle
Fore/Aft	Test (Anti-drive) end	
Fore/Aft	Test (Anti-drive) end	Lower center, housing flange plate
Fore/Aft	Test (Anti-drive) end	Lower side, housing flange plate

A schematic of the vibration pickup locations is shown by Figure 4.5-2.

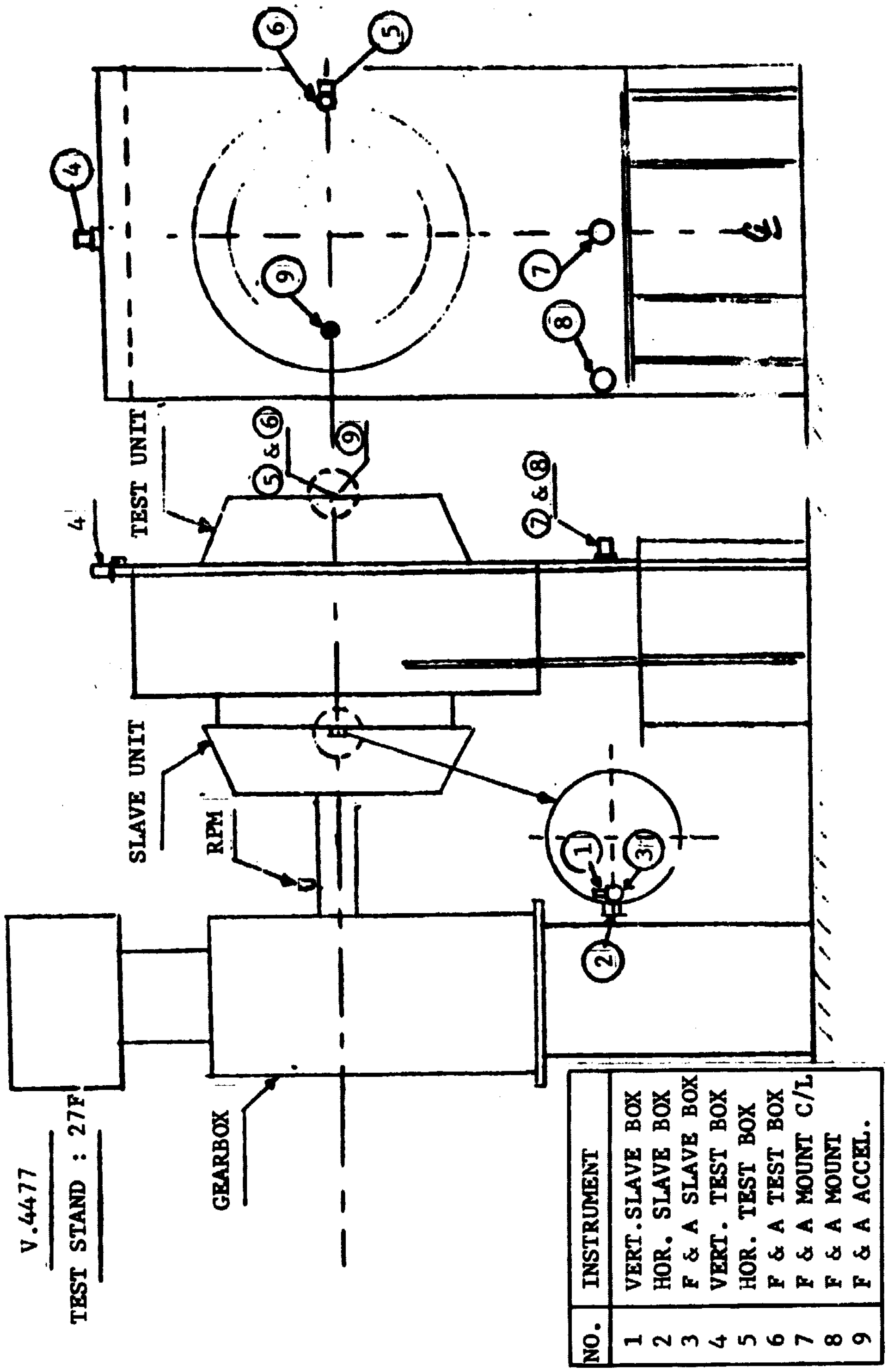
4.6 Test Procedure

4.6.1 Pre-Test Procedure

Prior to initial assembly, oil flows for each gear lubrication spray tube, each star gear support trunnion (bearing lubrication) and the star gear supports with bearings installed were checked abd flow versus pressure calibration curves plotted for reference. Oil flow to the test rig bearings was also checked.

The rig input shaft was dynamically balanced to 3.6 g-cm (.05 oz - inch) with the rig and gear unit couplings installed on the test unit end of the shaft. Index marks were placed on the coupling and shaft for always reinstalling the coupling in the as balanced position. The slave unit end rig and gear unit couplings were assembled and balanced as a separate subassembly to allow installation on the shaft in the relationship required for proper gear meshing and torque loading hydraulic ram position.

The ring gear connecting shaft and shrouds were dynamically balanced as a unit to 3.6 g-cm (.05 oz - inch) by rotating on the center support bearings mounted on a stationary shaft.



NO.	INSTRUMENT
1	VERT. SLAVE BOX
2	HOR. SLAVE BOX
3	F & A SLAVE BOX
4	VERT. TEST BOX
5	HOR. TEST BOX
6	F & A TEST BOX
7	F & A MOUNT C/L
8	F & A MOUNT
9	F & A ACCEL.

Figure 4.5-2 QCSEE Main Reduction Gear Vibration Instrumentation Locations

The gear units were installed in the test rig and gear tooth contact pattern checks performed at 25% and 120% of rated torque. A thin layer of red lead was applied to the test unit star gear teeth prior to installation. The torque loading was applied by the hydraulic rams and the sun gear shaft rotated manually. The test unit sun gear was then removed to provide access to the star gears. The contact patterns were lifted from the respective sun gear and ring gear contact faces of the star gear teeth using Scotch Magic tape and were mounted on a sheet of white paper stock.

All oil passages in the lubrication system and test rig were flushed and inspected prior to test operation. After completion of the pre-test operations the assembled test rig was installed on the test stand.

4.6.2 Test Operation

Development Engine Instruction (DEI) sheets are issued to provide detailed instructions for most assembly and test operations. Scheduled test operation was for short duration step-load tests with vibration and sound level characteristics surveys followed by cyclic speed/load operation simulating flight conditions and experimental engine operation. The proposed step-load test schedule is shown by Table 4-1. The proposed cyclic test schedule for the UTW unit is shown by Table 4-2 and for the OTW unit is shown by Table 4-3. Conditions encountered during the initial UTW unit test operation resulted in deviations from the planned schedules.

The assembled test rig is installed on the test stand and drive alignment established. Oil lines and instrumentation are connected and checked for proper operation. The oil temperature and oil flow rates are set in accordance with the DEI and a light torque load is applied to the gear unit prior to start-up. The scheduled sequence of load/speed/oil flow/oil temperature and any other variable parameter test points are prescribed in the DEI.

Test data are recorded on log sheets, generally at 15 minute intervals. Two classes of data were recorded: one pertaining directly to the reduction gear test units operation and one related to the general test facility operation. The reduction gear test unit data include:

a. Rig input speed
b. Rig driving torque
c. Torque loading hydraulic pressure
d. Gear unit oil supply pressure
e. Gear unit oil supply temperature
f. Oil out temperature
g. Gear unit oil supply flowmeter indicated frequency count
h. Gear unit bearing temperatures
i. Test rig vibration pickup readings.

The following data calculated from the above are also entered on the log sheets.

a. Rig driving horsepower
b. Simulated power locked in the gear train
c. Oil flows.

Data not directly related to the gear unit operation but used to monitor the operation or as a check on data from other sources include the following:

- **a. Time of day**
- **b. Dynamometer speed, current, voltage and calculated input power**
- **c. Test rig bearing oil supply pressures**
- **d. Test rig bearing oil supply and bearing cavity oil drain temperatures**
- **e. Dynamometer bearing temperatures**
- **f. Facility speed increaser bearing and oil temperatures**
- **g. Facility speed increaser vibration pickup readings**
- **h. Dynamometer field temperatures.**

In addition to data recorded on the log sheet, sound, vibration pickup and accelerometer data are recorded on tape for subsequent analysis. Also, at specified intervals oil samples are taken for spectrographic analysis for change in metallic content.

Following specified speed/load operating levels, the test unit sun gear is removed for visual inspection of the sun and star gear teeth. Removal of the test rig from the stand and complete disassembly of the reduction gear units for inspection of all gears and bearings is scheduled following specified operating time or speed/load milestones.

TABLE 4-1. QCSEE MAIN REDUCTION GEAR

PROPOSED STEP LOAD TEST SCHEDULE

Torque % Rated	Speed % Rated	Estimated Time Min/Test Pt
25	25, 50, 75, 100	15
50	25, 50, 75, 100	15
75	25, 50, 75, 100	15
100	25, 50, 75, 100	15
110*	25, 50, 75, 100	15
120**	25, 50, 75, 100	15

*OTW Unit Only
**UTW Unit Only

Oil MIL-L-23699
Oil inlet temperature . . . . . 185°F (358°K)

TABLE 4-2. UTW REDUCTION GEAR TEST CONDITIONS (PROPOSED)

Oil Inlet Temperature 185°F (358°K)

Phase I: Flight Conditions Simulation

2 - 2 Hour Cycles
5 - 8 Hour Cycles

Condition	Power		Fan Speed	2 Hour Cycle		Time - Hr:Min 8 Hour Cycle	
	HP	kW	RPM	Cycle	Total	Cycle	Total
Idle-Taxi*	317	236	973	0:15	0:30	1:00	5:00
T-O	13019	9712	3157	0:15	0:30	1:00	5:00
Climb	14097	10516	2984	0:15	0:30	1:00	5:00
Climb	11488	8570	3104	0:15	0:30	1:00	5:00
Climb/Approach	8594	6411	3340	0:15	0:30	1:00	5:00
Cruise	7907	5899	3408	0:15	0:30	1:00	5:00
Cruise/Descent	2346	1750	1985	0:30	1:00	2:00	10:00
Total					4:00		40:00

*Experimental engine operation point.

Phase II: Experimental Engine Operation Points (Proposed)

4 - 1-1/2 Hour Cycles

Condition	Power		Fan Speed	Time - Hr:Min 1-1/2 Hour Cycle	
	HP	kW	RPM	Cycle	Total
Min Speed/Torque*	100	75	902	0:15	1:00
High Time	6571	4902	2433	0:15	1:00
Max Torque	15830	11809	3119	0:15	1:00
High Torque @ RPM	14709	10973	3157	0:15	1:00
Overshoot	15907	11867	3300	0:15	1:00
Max Speed	13142	9804	3406	0:15	1:00
Total					6:00

*Flight cycle idle-taxi

TABLE 4-3. OTW REDUCTION GEAR TEST CONDITIONS (PROPOSED)

Oil Inlet Temperature 185°F (358°K)

Phase I: Flight Conditions Simulation

5 - 2 Hour Cycles
18 - 8 Hour Cycles

Condition	Power		Fan Speed	Time - Hr:Min			
				2 Hour Cycle		8 Hour Cycle	
	HP	kW	RPM	Cycle	Total	Cycle	Total
Idle-Taxi*	833	621	1137	0:15	1:15	1:00	18:00
T-O/Climb	16351	12198	3596	0:15	1:15	1:00	18:00
T-O/Rev	16910	12615	3860	0:15	1:15	1:00	18:00
Climb	13685	10209	3686	0:15	1:15	1:00	18:00
Cruise	8756	6532	3657	0:15	1:15	1:00	18:00
Approach	9009	6721	3104	0:15	1:15	1:00	18:00
Cruise/Descent	2136	1593	2365	0:30	2:30	2:00	36:00
Total					10:00		144:00

*Experimental engine operation point.

Phase II: Experimental Engine Operation Points (Proposed)

4 - 1-1/2 Hour Cycles

Condition	Power		Fan Speed	Time - Hr:Min 1.5 Hour Cycle	
	HP	kW	RPM	Cycle	Total
Min Speed/Torque*	100	75	573	0:15	1:00
High Time	8399	6266	2844	0:15	1:00
Max Power/Torque	18579	13860	3793	0:15	1:00
High Time	13438	10025	3413	0:30	2:00
Max Speed	16799	12532	3982	0:15	1:00
Total					6:00

*Flight cycle idle-taxi

4.7 Data Reduction Procedure

The classes of test data of primary interest were:

a. Operating temperatures
b. Efficiency
c. Vibration characteristics.

In general, the temperature data were reduced to a temperature differential between the temperature of the oil entering the gear units and the temperature parameter being analyzed for comparisons.

Efficiency is the relationship between driving power for the rig or power losses and the simulated power locked into the gear units. Mechanical driving power is calculated from the torque indicated by the torquemeter and the speed. This results in the total power loss in the test rig. Electrical driving power is calculated from the dynamometer electrical input amperes and volts. In addition to the total power loss in the test rig, the latter includes the facility speed increaser losses and the electrical inefficiency of dynamometer. Heat dissipation to the oil flowing through the gear unit calculated from the flow rate and the temperature rise indicates the individual gear unit power losses.

The following equation is used for calculating the simulated power locked into the gear units installed in the test rig.

$$P = \frac{p \times N}{C \times 63{,}024}$$

where

P = power, hp
p = hydraulic pressure, psi
N = input speed, rpm
C = constant

"C" is a function of the hydraulic ram piston area, number of rams, torque arm lengths, angle between the hydraulic ram axis and the torque arms, and the ratio between the torque at the star gear support and at the input shaft.

For the UTW unit the equation becomes

$$P_u = \frac{p \times N}{253.23}$$

and for the OTW unit

$$P_o = \frac{p \times N}{223.78}$$

The electrical input power is calculated by

$$P_E = \frac{V \times A}{746}$$

where

P_E = power, hp
V = volts
A = amperes

The input power indicated by the torquemeter is calculated by

$$P_T = T_m \times N \div 63{,}024$$

where

P_T = power, hp
T_m = input torque, lb-in.
N = input speed, rpm

The heat rejection equivalent power is calculated by

$$P_H = \frac{W \times c \times \Delta T}{42.4}$$

where

P_H = heat power, hp
W = oil weight flow, lb/min
c = specific heat of oil, Btu/lb/°F
ΔT = temperature of oil out - temperature of oil in, °F
42.4 = Btu/min/hp

Data presentation is in the form of tables and graphs.

5.0 DISCUSSION OF RESULTS

5.1 General

The design 100% power and speed condition for the UTW unit reduction gear is 9712 kW (13019 hp) and 7782 rpm input speed (3157 rpm fan speed). Satisfactory operation was demonstrated at the following conditions.

Condition	Power kW	Power (hp)	Torque %	Speed rpm	Speed (%)
Maximum Power	12172	(16316)	125	7781	(100)
Maximum Speed	5152	(6906)	50	8250	(106)

Corresponding UTW maximum gear pitch line velocity at 8250 rpm was 103.4 m/s (20360 fpm), and the maximum star gear spherical roller bearing DN was 0.79 x 10^6, based on the bearing bore (stationary) in millimeters times the outer race (star gear) rotational speed in rpm.

The design 100% power and speed condition for the OTW unit reduction gear is 12615 kW (16910 hp) at 7961 rpm input speed (3861 rpm fan speed). Satisfactory operation was demonstrated at the following conditions.

Condition	Power kW	Power (hp)	Torque %	Speed rpm	Speed (%)
Maximum Power	11342	(15204)	100	7148	(90)
Maximum Speed	5993	(8034)	50	7554	(95)
Maximum Torque	11057	(14822)	112	6200	(78)

Corresponding OTW maximum gear pitch line velocity was 113.3 m/s (22,330 fpm) and the maximum star gear spherical roller bearing DN was 0.85 x 10^6. Operation at maximum torque was for one hour during the DEI QCSEE-16 schedule.

Conditions encountered during the test operation resulted in deviations in the test schedule and at times redirection of the effort. Two areas of concern were a greater than anticipated power loss attributable to oil churning and an apparent excursion of the star gears from the plane of rotation.

5.2 UTW Reduction Gear

5.2.1 Test Program

The first scheduled UTW reduction gear unit dynamic test operation, DEI QCSEE-8, consisted of step-load tests as shown in Table 4-1 with an oil inlet temperature of 358°K (185°F). The test schedule was interrupted following the 5840 rpm (75% speed) at 25% torque point because of high input power requirement (dynamometer overload circuit breaker tripped) and an increasing oil out temperature rise rate. The test unit gears were inspected and found satisfactory.

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Oil out temperature data indicated that the heat rejection from the slave gear unit end of the test rig was more than 2-1/2 times that for the test gear unit. Since the only apparent significant difference between the two sections of the rig was the General Electric Company engine configuration screen baffle around the test gear unit and the absence of a baffle around the slave gear unit, it was concluded that a screen baffle was also needed around the slave gear unit. A screen baffle previously designed and fabricated for the test unit end of the rig but replaced by the General Electric Company engine configuration screen was installed in the slave unit end, and the slave unit outlet drain was increased from 3 inch diameter pipe to 4 inch diameter pipe.

Also encountered during the initial test operation was apparent oil contamination of the slip rings transmitting the signals from strain gages on the test unit ring gear, an indication of excessive oil in the center of the rig where it was not anticipated. Reliable strain gauge readings were never obtained during any of the subsequent tests.

The original step-load test operation schedule was resumed, DEI QCSEE-9. Although temperature data indicated apparent improvement in the slave unit heat rejection rate, the dynamometer overload circuit breaker again interrupted the test operation at approximately 6000 rpm and 25% torque load. A dynamometer problem was identified and corrected.

Although the highest input speed, indicated by the torquemeter speed signal, at which a full set of data was obtained was 6600 rpm, an indicated speed of 7500 rpm at 25% torque was observed before the test operation was again interrupted by the dynamometer overload circuit breaker. Subsequently, an error in the speed indicated by the torquemeter above approximately 6200 rpm was discovered and the actual speed at the 6600 rpm indicated speed was approximately 6825 rpm and the 7500 rpm indicated speed was approximately 7900 rpm.

A review of the data indicated higher than anticipated oil out temperatures and power requirement. Test operation resumed in accordance with the step-load schedule to obtain data at higher torque loads for analysis except that the maximum speed was limited to 5837 rpm (75%). Test unit gears were fourd satisfactory at inspections following operations through 5837 rpm at 50%, 75%, 100% and 120% torques.

Analysis of test data indicated excessive oil churning, possibly from inadequate oil scavenging. The oil churning and heat generation was of major concern since the test unit reduction gear surrounding walls, baffle screen and scavenge oil drain in the rig simulated the UTW engine configuration and was a potential problem in the engine operation. Heat generation data was reviewed with General Electric personnel and various modifications to the test were discussed.

At General Electric's request, test operation was resumed with the oil inlet temperature reduced to 311°K (100°F) to obtain additional data on the oil churning and heat generation characteristics, DEI QCSEE-10. Test points requested were speeds of 2000, 3000, 4000, and 5000 rpm; 6000 to 7000 rpm in 200 rpm increments; and 7000 to 8400 rpm in 100 rpm increments at 25% torque load. Oil-in to oil-out temperature differential versus speed was the primary

interest. Determination of the amount of oil trapped in the rig versus operating speed as determined by the change in weight of the oil in the supply tank located on a platform scale was also of interest. At this time a 24 channel temperature recorder was installed to provide a continuous record of transient and stabilized temperatures for inlet oil, outlet oil and star gear bearings. Test was interrupted at 6800 rpm because of concern from an apparent increase in the rate of oil temperature rise and relatively high differentials for oil-in to oil-out and oil-in to bearing temperatures.

Temperature and scavenging data were reviewed by a coordinating group of Curtiss-Wright and General Electric Company personnel and oil outlet deflector (scoop or baffle) configurations were developed for both the test gear unit and slave gear unit sections of the rig.

Deflectors were fabricated and installed and the same test operation as for the preceding test was scheduled, DEI QCSEE-10A. No significant change in the test unit oil temperature differentials with 311°K (100°F) oil inlet temperature was noted at speeds up through 6200 rpm, although a slight improvement was apparent in the slave unit oil out temperature. Operation at 6000, 6200, 6400 and 6600 rpm was conducted with an oil inlet temperature of 339°K (150°F). A substantial reduction in oil out and bearing-to-oil temperature differentials as related to the oil inlet temperature was observed, as would be expected.

Continued concern over the apparent oil scavenging condition resulted in a request by General Electric Company for modification of the planned program to include rig hardware modifications and subsequent test operation in an attempt to solve this problem before continuing with the originally planned test program.

The following modifications were incorporated in the test rig and reduction gear hardware.

Slave unit side of test rig:

a. Removed the simulated variable pitch mechanism support and replaced with thermocouple instrumented washers.

b. Relieved ring gear axial positioning bosses in the output shaft shroud to increase oil passage area to improve oil scavenging past the aft end of the ring gear.

c. Removed oil outlet screen baffle.

d. Designed, fabricated and installed improved internal scoop for main oil outlet.

e. Designed, fabricated and installed scavenge pipes in the lower section of rig intermediate housing (slave gear unit end of rig).

f. Relieved internal flange in rig housing to improve flow from intermediate housing to main drain.

g. Increased oil outlet pipe to six inch diameter, the largest size feasible, from four inch diameter pipe.

h. Added small adjustable height standpipe in the bottom of the intermediate housing.

Test unit side of test rig:

a. Modified reduction gear oil manifold to provide aft axial oil drains in the vicinity of the star gear bearings.

b. Relieved ring gear axial positioning bosses in the output shaft shroud to increase oil passage area and improve oil scavenging past the aft end of the ring gear.

c. Modified width of output shaft shroud flange for clearance with the General Electric Company revised oil baffle screen.

d. Rebalanced output shaft with revised shrouds installed.

e. Installed solid dynamic-type baffle and new scoop on test screen.

f. Relieved internal flange in rig to improve oil flow from forward side of the output shaft to the main scavenge drain.

g. Added small adjustable height standpipe in bottom of housing.

The adjustable height standpipes were one of several attempts to determine the operating oil level in the bottom of the rig. Connections from the three scavenge pipes in the intermediate housing to the main oil outlet pipe were made with clear Tygon tubing so as to be able to observe oil flows during operation.

The oil scavenging investigation, DEI QCSEE-11, continued with an operating schedule of 50% torque at 2000, 3000, 4000 and 5000 rpm; 6000 to 7000 rpm in 200 rpm increments; and 7000 to 8400 rpm in 100 rpm increments and an inlet oil temperature of 355 - 358°K (180 - 185°F). All points up through approximately 8250 rpm were accomplished.

A negative pressure of approximately 2 inches of oil was observed on the oil drain from the end cover on the test unit end of the rig (the area inside the star gear support) during this test operation. This indicated an apparent reverse oil flow instead of draining. Also noted was an unexpected contact pattern on the test unit gears. Test rig was disassembled for further inspection of gears and bearings.

A contact pattern on the star gear teeth showing apparent both lower and higher contact toward the ends of the teeth than at the center was observed in both the sun gear and ring gear mesh sides of the teeth. This pattern was peculiar to the test unit gearing and had not been previously seen. There was no discernable change in the pattern on the slave unit gears.

Two test gear unit star gear spherical roller bearings were found to have distress markings on the inner race roller path. These were replaced with new star gear and bearing assemblies and the removed parts were submitted to the vendor for analysis.

The observed gear contact patterns and the bearing distress, including immediately preceeding operation history, were reviewed to identify possible contributing factors. Suggested factors were: hydraulic effects of the current General Electric Company dynamic-type baffle screen configuration, the higher speed attained during the latest run, reduced oil viscosity resulting from the observed higher bearing operating temperatures, bearing roller skidding and dynamic unbalance or vibration characteristics.

Test operation plans were redirected toward investigating and identifying the cause of the observed gear tooth contact patterns. The new test schedule, DEI QCSEE-12, included rig reassembly and operation to 7000 rpm input speed at 50% torque with an inlet oil temperature of 347°K (165°F). This operation resulted in contact patterns on the new test unit gears similar to those previously noted. This indicated that the condition occurred at 7000 rpm or lower speed.

The situation was reviewed with General Electric Company and NASA personnel. The General Electric Company dynamic-type screen baffle was removed and an oil outlet deflector (scoop) was fabricated and installed in the test unit end of the rig. One star gear was replaced so as to have a virgin tooth surface for observing new contact patterns. A new pre-test gear tooth contact pattern check was performed at 50% takeoff torque and found to be very good. The test operation schedule, DEI QCSEE-12A, included gear inspections after 2000, 4000, 6000, 7000, 7600 and 8400 rpm at 50% torque. Testing was again terminated following the 7000 rpm operation when gear contact patterns similar to those previously observed were noted. Test results, and rig and reduction gear vibration data were reviewed with General Electric Company and NASA personnel. The test rig was checked for natural frequencies.

Modifications for the next test operation included installation of a pedestal support for the torquemeter, test rig realignment and the installation of proximity pickups to measure radial motion of the input shaft. Vertical and horizontal proximity pickups were located at each end of the shaft and a horizontal pickup was located at the shaft center, actually measuring motion of the output shaft connecting hub. Also, the silver was stripped from the sun gear and a copper flash added to provide a more readily visible gear contact pattern.

The scheduled operating conditions, DEI QCSEE-12B, included operation to 6000 rpm at 50% torque, gear inspection, operation to 7000 rpm at 60% torque, gear inspection, operation to 7800 rpm at 65% torque and 8400 rpm at 70% torque with gear inspections following each of the operating conditions. All points through 7800 rpm were accomplished but 8200 rpm at 60% torque replaced the last scheduled point. During this test operation speed checks with the dynamometer tachometer and revolution counter, operating vibratory frequencies and the digital preset counter signals from the torquemeter speed indicator pickup showed that the torquemeter digital preset counter readout was low

when the speed was above approximately 6200 rpm. A bench check of the unloaded torquemeter indicated speed showed correct speed indication through 8000 rpm. Recorded test rig input speeds thereafter are based on the dynamometer speed.

Gear inspection at the completion of the test indicated similar star gear contact patterns as previously seen but with no significant progression. Therefore the gears were considered to be satisfactory for continued test operation. An oscillograph record was made of the complete upper speed range at shutdown for analysis to determine if critical speeds existed which needed to be avoided during long term operation. Measured test rig excitation forces were reduced considerably, but the effect on the gear contact pattern was not definitive.

A revised test program with a reduction in time and number of test operating points was proposed by General Electric Company to replace the originally planned test program. This program included simulating a cold oil, 20°K (69°F), engine start-up. This test schedule, DEI QCSEE-12C, included the following operating points with no changes in the test hardware.

Flight Condition	Input Speed rpm	Torque %	Simulated kW	Power Hp	Oil Flow %	Time Hr
Idle 1	4000	30	1496	2006	80	1.0
Idle 2	5200	25	1623	2175	80	.5
Reverse	6270	73.3	5744	7700	100	.5
Approach	7560	54.7	5167	6926	90	1.0
Takeoff	7560	95.6	9042	12121	100	1.0
Fan Map	7781	120.0	11654	15622	100	.25

Oil Temperature . . . . 344°K (160°F)
100% Oil Flow . . . . . 83.5 kg/min (184 lb/min)

Gear inspections were performed following the 7560 rpm at 54.7% torque and 7560 rpm at 95.6% torque test points. The gear contact patterns in the test gear unit showed apparent heavy star gear tip loading on the flank of the sun gear. An involute check also showed wear patterns deeper at the ends of the sun gear teeth than at the center.

Proposed regrinding of the test unit sun gear to modify the tooth profile for relief of star gear tip loading and to increase the backlash was reviewed with General Electric Company and NASA personnel and approval to proceed was received. The previous test vibration data was also reviewed with General Electric Company and NASA personnel. No critical operating points were apparent although some frequencies did blossom at approximately 3900 and 6750 rpm. The torquemeter pedestal support did decrease and control amplitudes. The gear tooth wear indicated apparent rocking or wobble of the star gears.

New instrumentation incorporated for the final test operation included horizontal and vertical accelerometers attached to the test unit star gear support and two proximity pickups to measure the rocking or wobble excursions of one test unit star gear. The test unit sun gear teeth were silver plated after

regrinding. The General Electric Company engine configuration baffle screen was not installed for this test.

The final test operation, covered by DEI QCSEE-13, included the following schedule specified by General Electric Company to cover representative flight spectrum and experimental UTW engine operating conditions. This schedule consists of shorter interval surveys of operation at each point followed by longer duration operation at specified points.

Condition	Input rpm	Power Hp	Power kW	Oil Flow GPM	Oil Flow lb/min	Oil Flow kg/min	Time-minutes 1st Test	Time-minutes 2nd Test
Idle (1)	4000	2014	1502	22	176	80	10	-
	4000	2014	1502	18.4	147	67	10	60
Idle (2)	5200	2220	1656	22	176	80	10	-
	5200	2220	1656	18.4	147	67	10	60
Reverse	6270	7697	5742	22	176	80	10	15
Gear Inspection								
Approach	7560	6930	5170	22	176	80	10	15
	7560	6930	5170	19.8	158	72	10	-
Gear Inspection								
T.O.	7560	13218	9861	22	176	80	10	-
	7560	13218	9861	21.4	171	78	10	25
	7781	13593	10140	22	176	80	10	25
	8000	15372	11468	23	184	83	10	25
Gear Inspection								
Fan Map	7781	16311	12168	22	176	80	10	30

All scheduled points were satisfactorily completed. Following disassembly, the sun gears, ring gears and star gear supports were magnetic particle inspected, the star gears and bearings were visually inspected, the gears were measured for wear and the oil manifolds were fluorescent penetrant inspected. Parts were then shipped to General Electric Company for installation in the engine. The total operating time for the QCSEE MRG UTW Units was approximately 48.75 hours.

5.2.2 Oil Temperatures

Curves of oil temperature rise versus input sun gear speed are presented in Figures 5.2-1 through 5.2-5 for a constant oil flow rate of about 86 kg/min (27 gpm). All data are for the test unit except Figure 5.2-2 which shows slave unit data for QCSEE-8 and QCSEE-9 test operations. These slave unit data are presented to show comparison between QCSEE-8 operation with a 3" dia outlet drain pipe and without the screen baffle in the slave unit end of the test rig, and the QCSEE-9 test operation with a 4" dia outlet drain pipe and the screen installed. A general similarity exists for the slopes of the

curves in the higher speed ranges, however, at the 1950 rpm speed the temperatures had relatively inconsistent wide variations and in most cases have been disregarded.

The lowest test unit oil temperature rise occurred during the QCSEE-8 test operation, Figure 5.2-1. A specific reason for the higher oil temperature rise observed under apparently identical test unit operating conditions during QCSEE-9 test operation could not be identified. A possibility is that the installation of a larger 4" dia outlet drain and the screen in the slave unit end of the test rig had an unidentifiable effect on the general oil flow pattern within the rig.

The increases in oil temperature rise with increasing torques were relatively consistent except for an overlap of the 50% and 75% torque data points on the slave unit, Figure 5.2-2. The broken line between the 5850 rpm point at 25% torque shows the observed speed and the solid line represents the speed resulting from correction of the speed indicator error in this speed range later detected. A general projection of the oil temperature rise places the maximum temperature rise for 7782 rpm (100%) input speed at approximately 37°K (67°F) for an oil out temperature of approximately 394°K (250°F), which can be considered moderate.

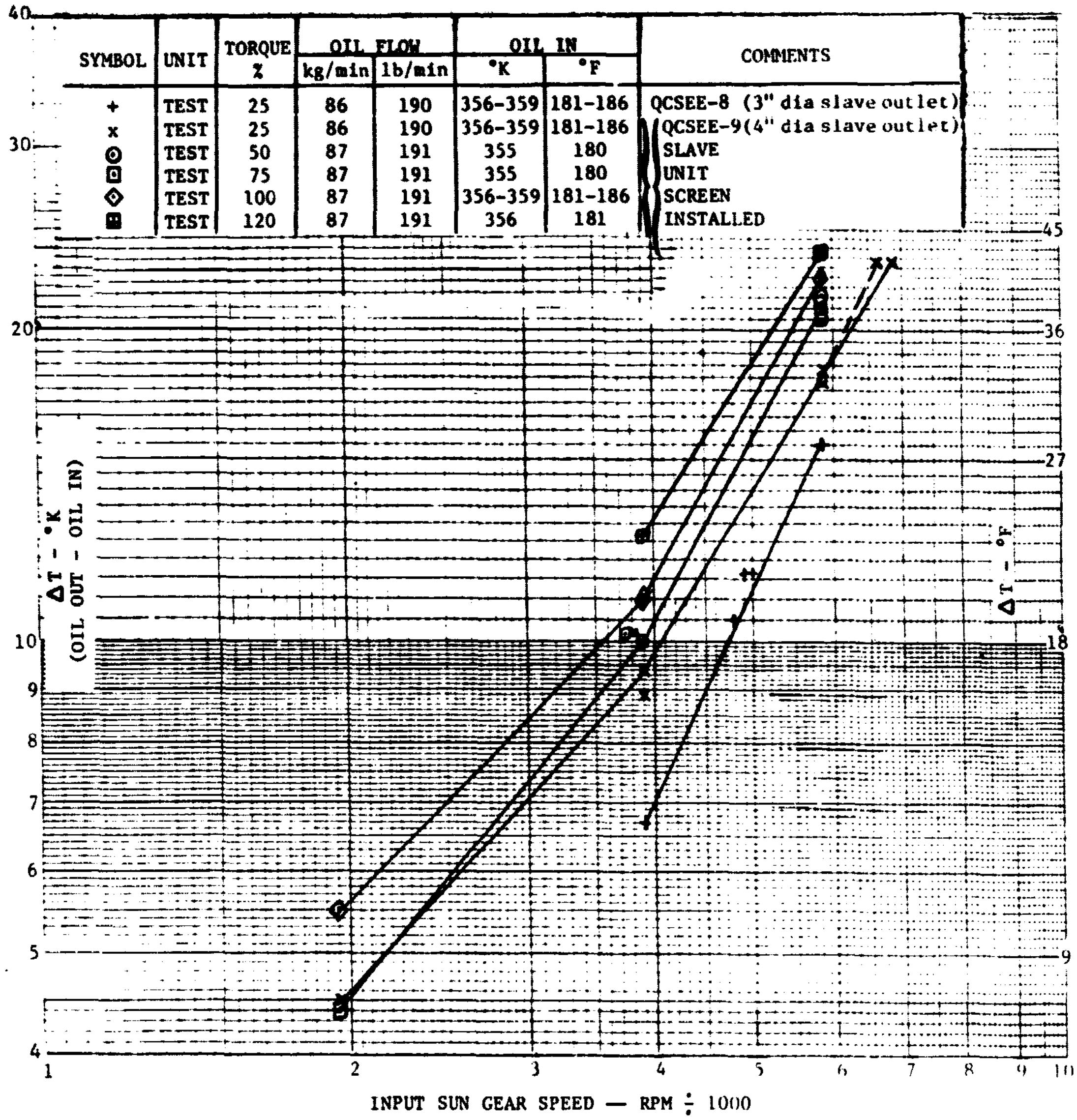
The major significance of the data presented by Figure 5.2-2 is that the increased 4 inch diameter outlet drain pipe and the installation of the scavenge screen reduced the slave unit oil temperature considerably. The inconsistency apparent in 50%, 75% and 100% load oil temperature rises is attributed to dumping of the oil from the bearings supporting the output shaft on the input shaft into the slave unit scavenging cavity.

The effect of the lower temperature inlet oil, 311°K (100°F) nominal, and resulting higher oil viscosity for QCSEE-10 test operation is shown by Figure 5.2-3. For comparison purposes, at 4000 rpm the temperature rise increase is 4°K (7°F) and at 6800 rpm it is 6.6°K (12°F) over that for the 355°K (180°F) inlet oil temperature. Four points in the 6000 to 6800 rpm range run with 339°K (150°F) inlet oil temperature are also shown. These oil temperature rises project to approximately 37°K (67°F) at 7782 rpm for an oil out temperature of 348°K (167°F), with an inlet oil temperature of 311°K (100°F).

Oil temperature rise versus speed data at 50% torque with the several modifications incorporated in the test rig and test hardware, DEI QCSEE-11 test operation, are shown by Figure 5.2-4. Also shown on this curve are the data for two speed points run during DEI QCSEE-9 test operation at similar operating conditions. These data indicate a small improvement in the oil temperature rise for the test unit reduction gear, approximately 1°K (2°F) at 6000 rpm and approximately 2°K (4°F) when projected to 7782 rpm.

The number and nature of the several modifications made it impossible to identify the effect of any individual modification. The number of data points are sufficient to provide a valid data curve. The approximate oil temperature rise at 7782 rpm is 33°K (60°F) and the oil out temperature with an oil in temperature of 355°K (180°F) is approximately 389°K (240°F), an acceptable operating temperature.

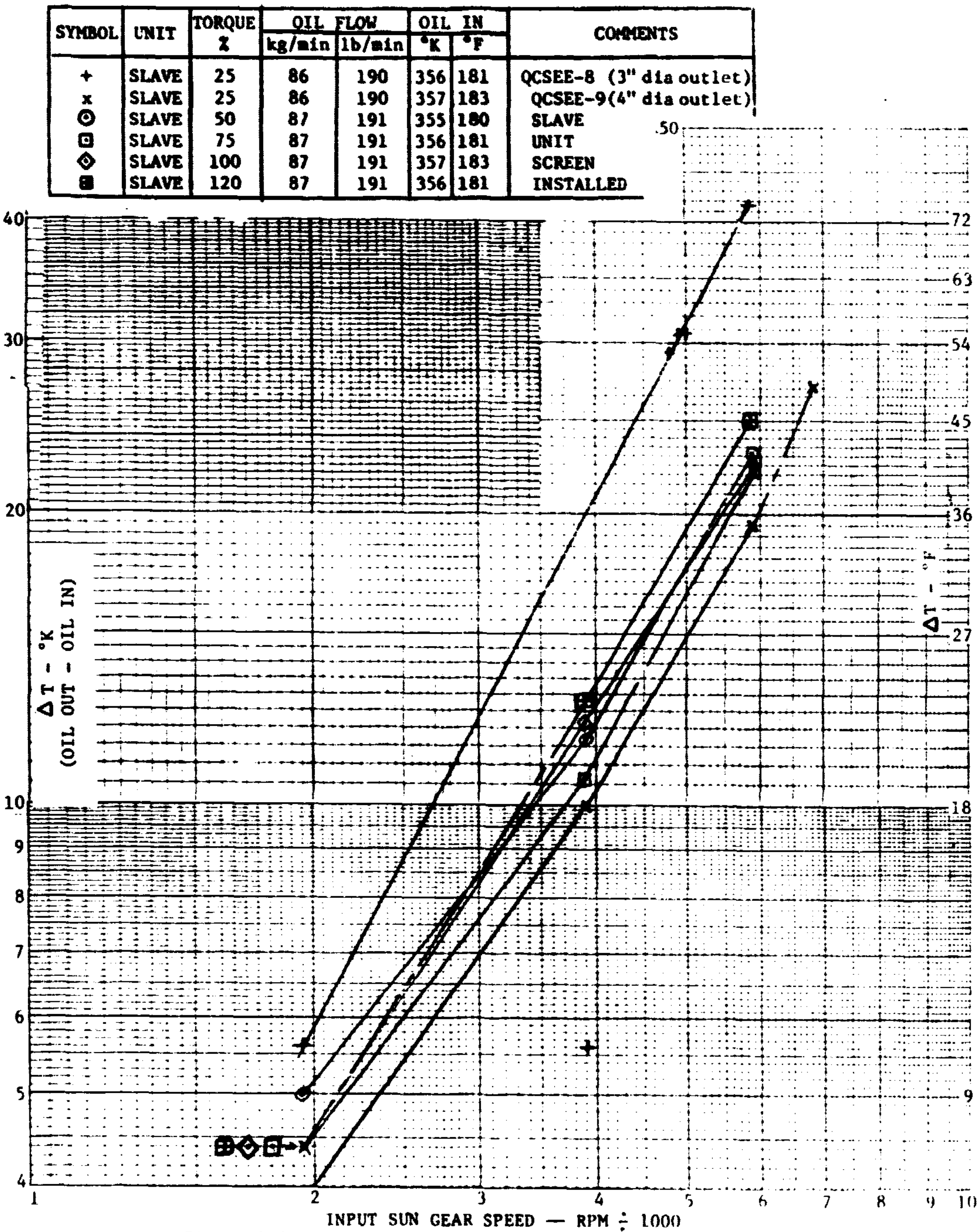
DEI QCSEE - 8 AND 9



SYMBOL	UNIT	TORQUE %	OIL FLOW kg/min	OIL FLOW lb/min	OIL IN °K	OIL IN °F	COMMENTS
+	TEST	25	86	190	356-359	181-186	QCSEE-8 (3" dia slave outlet)
x	TEST	25	86	190	356-359	181-186	QCSEE-9(4" dia slave outlet)
⊙	TEST	50	87	191	355	180	SLAVE
⊡	TEST	75	87	191	355	180	UNIT
◇	TEST	100	87	191	356-359	181-186	SCREEN
▣	TEST	120	87	191	356	181	INSTALLED

Figure 5.2-1. QCSEE Main Reduction Gear - UTW Test Unit Oil Temperature Rise vs Speed

DEI QCSEE - 8 AND 9



SYMBOL	UNIT	TORQUE %	OIL FLOW		OIL IN		COMMENTS
			kg/min	lb/min	°K	°F	
+	SLAVE	25	86	190	356	181	QCSEE-8 (3" dia outlet)
x	SLAVE	25	86	190	357	183	QCSEE-9(4" dia outlet)
⊙	SLAVE	50	87	191	355	180	SLAVE
⊡	SLAVE	75	87	191	356	181	UNIT
◈	SLAVE	100	87	191	357	183	SCREEN
▣	SLAVE	120	87	191	356	181	INSTALLED

Figure 5.2-2. QCSEE Main Reduction Gear - UTW Slave Unit Oil Temperature Rise vs Speed

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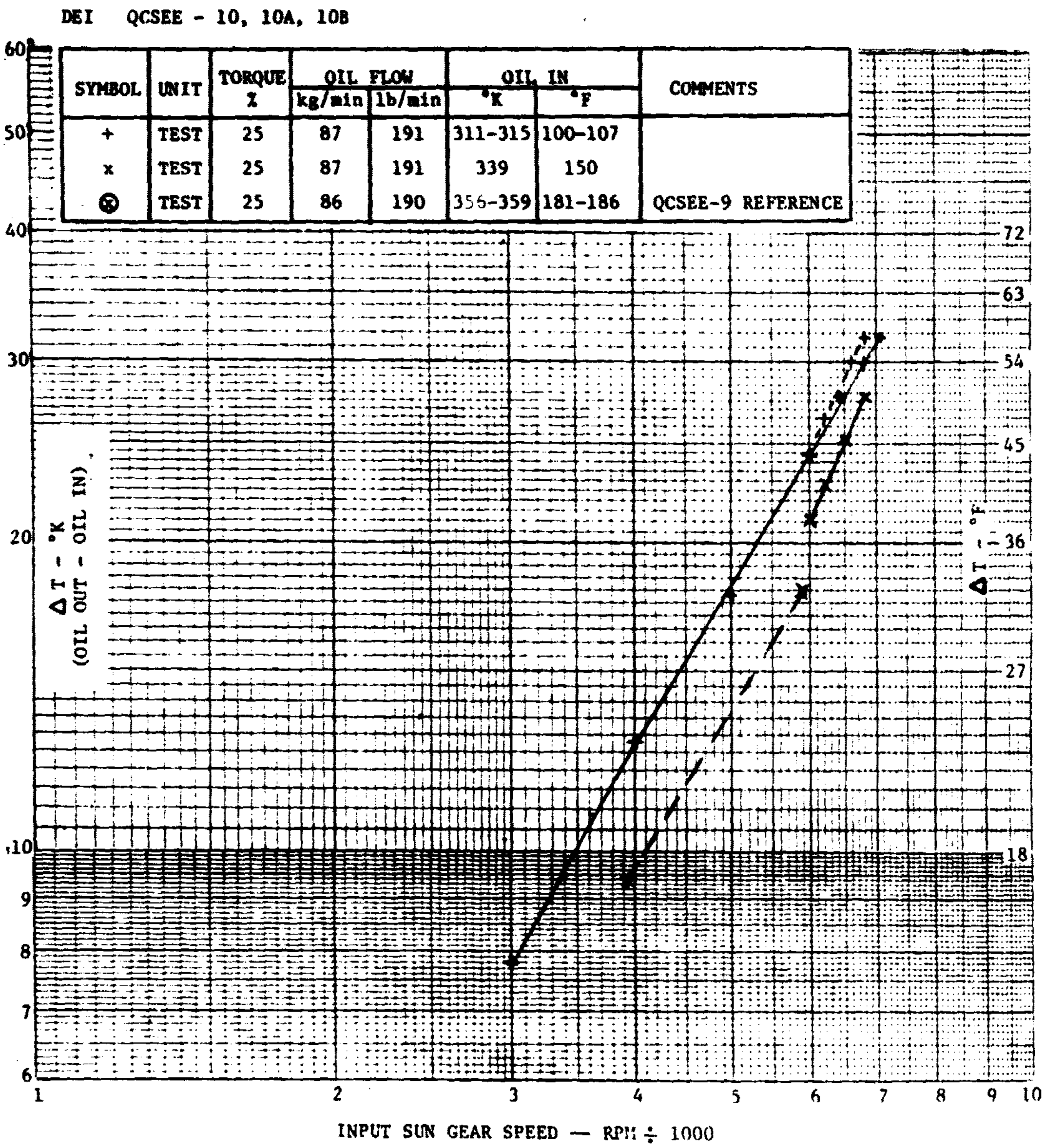
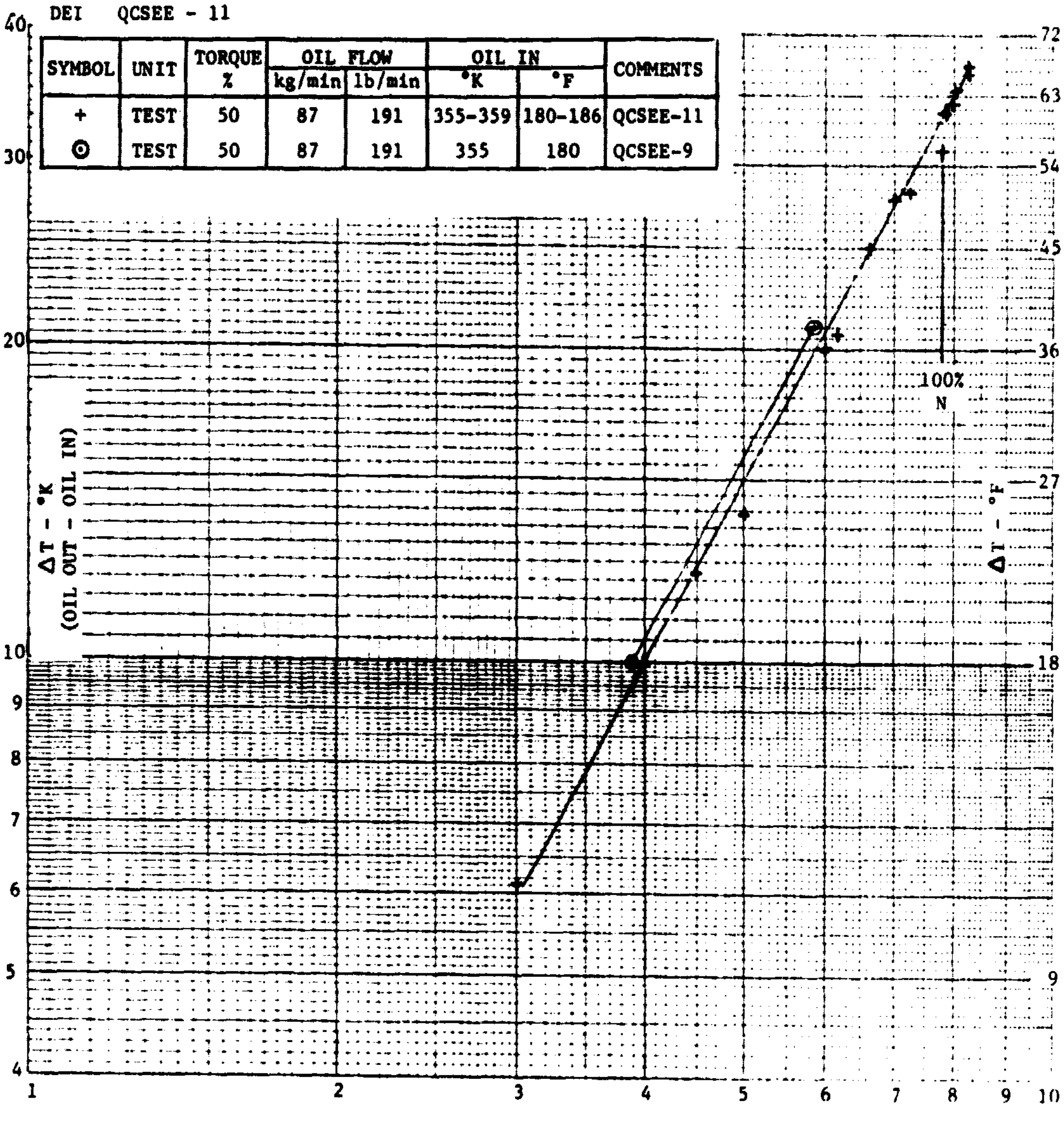


SYMBOL	UNIT	TORQUE %	OIL FLOW		OIL IN		COMMENTS
			kg/min	lb/min	°K	°F	
+	TEST	25	87	191	311-315	100-107	
x	TEST	25	87	191	339	150	
⊗	TEST	25	86	190	356-359	181-186	QCSEE-9 REFERENCE

Figure 5.2-3. QCSEE Main Reduction Gear - UTW Test Unit
Oil Temperature Rise Vs. Speed



SYMBOL	UNIT	TORQUE %	OIL FLOW		OIL IN		COMMENTS
			kg/min	lb/min	°K	°F	
+	TEST	50	87	191	355-359	180-186	QCSEE-11
⊙	TEST	50	87	191	355	180	QCSEE-9

INPUT SUN GEAR SPEED - RPM ÷ 1000

Figure 5.2-4. QCSEE Main Reduction Gear - UTW Test Unit
Oil Temperature Rise Vs. Speed

Although DEI QCSEE-12 series test operations were primarily for investigation of the operating gear contact patterns, the oil temperature rise is plotted in Figure 5.2-5 for a check on previously obtained data. At this point the oil in temperature was reduced from 355°K (180°F) to 344°K (160°F) which limits direct comparison to the prior test data. The oil temperature rise versus speed under conditions similar to previous operating conditions except for oil inlet temperature shows good correlation with the previous data, the inlet temperature effect being very small.

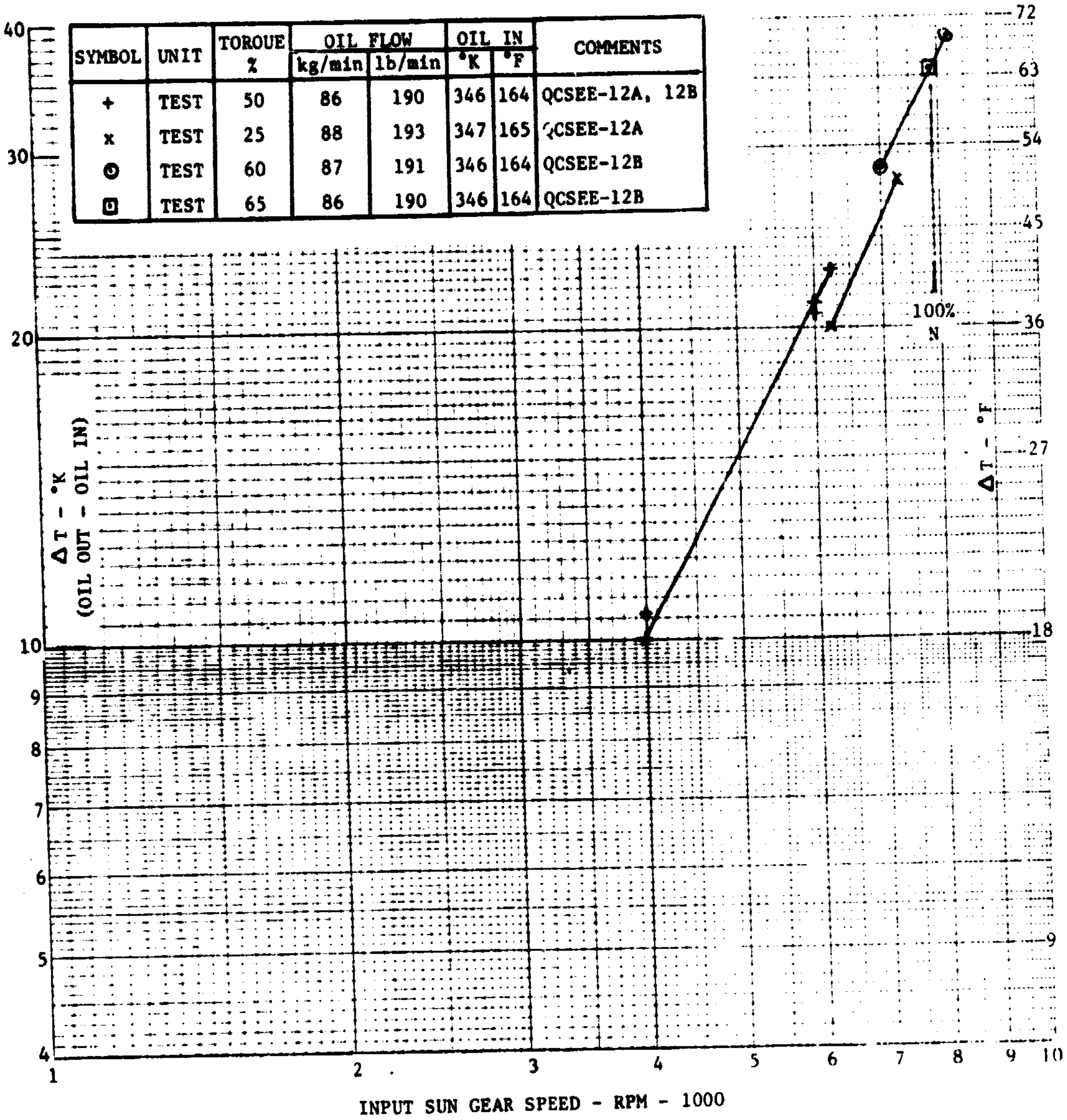
The data for DEI QCSEE-12C and QCSEE-13 test operation are presented in Tables 5-1 and 5-2, respectively, since the variety of speed, torque and oil flow rate combinations together with the absence of multiple test points with parameter commonality precludes the plotting of curves. It is possible, however, to associate certain test point data with data projected from previous similar but not identical operation. The oil temperature rise for similar test conditions show close correlation throughout the test program, indicating the several modifications had little effect on the oil temperature rise. The DEI QCSEE-12C and QCSEE-13 test operations were with reduced oil flows. Comparisons between oil temperature rise data for similar load and speed points and for decreasing oil flows show increasing oil temperature rises, as is to be expected. An example of this condition is the 5200 rpm at 25% torque operation.

Speed rpm	Torque %	Oil Flow Rate kg/min	(lb/min)	Oil Temperature Rise °K	(°F)	Test Operation
5200	25	88	(193)	13.9	(25)	QCSEE-12A
5200	25	86	(190)	14.9	(27)	QCSEE-9
5210	25.5	84	(184)	16	(28)	QCSEE-12C
5200	25.5	80	(176)	16	(28)	QCSEE-13
5200	25.5	67	(148)	17	(30)	QCSEE-13
5204	25.5	67	(147)	18	(32)	QCSEE-12C

The oil temperature rise and the resultant oil out temperature with oil in temperatures up through 358°K (185°F) is satisfactory. At 7781 rpm (100% speed) and 12,172 kW (16,316 hp) (125% torque) with 80 kg/min (177 lb/min) oil flow entering at 346°K (163°F) the oil out temperature is 385°K (234°F), a very conservative value.

5.2.3 Bearing Temperatures

The star gear bearing inner race to inlet oil temperature differentials shown in Tables 5-1 and 5-2 for DEI QCSEE-12C and QCSEE-13 test operations are representative of those for the earlier test operations. Up to approximately 6000 rpm input speed, the bearing temperature rise and oil temperature rise are essentially the same. Above 6000 rpm the oil temperature rise tends to be greater than the bearing temperature rise. At approximately 8000 rpm input speed, 11,165 kW (14,967 hp) the oil out temperature was 386°K (236°F) and the average bearing temperature was 382°K (229°F).



SYMBOL	UNIT	TORQUE %	OIL FLOW		OIL IN		COMMENTS
			kg/min	lb/min	°K	°F	
+	TEST	50	86	190	346	164	QCSEE-12A, 12B
x	TEST	25	88	193	347	165	QCSEE-12A
⊙	TEST	60	87	191	346	164	QCSEE-12B
▣	TEST	65	86	190	346	164	QCSEE-12B

Figure 5.2-5. QCSEE Main Reduction Gear - UTW Test Unit
Oil Temperature Rise Vs. Speed

Star gear bearing inner race temperature differentials for selected DEI QCSEE-13 operating points are presented by Figure 5.2-6. The two 7560 points show the effect of oil flow on the bearing to oil temperature differential, 72 kg/min (159 lb/min) versus 80 kg/min (175 lb/min). The third set of points represents 100% speed at 125% torque operation. The temperature differentials for 7996 rpm at 111.8% torque were essentially the same as for 100% speed at 125% torque.

The bearing temperature differential pattern relative to bearing location was checked but a conclusive relationship could not be established. Also individual bearing temperatures at the 8250 rpm operation, DEI QCSEE-11, the last operation before the bearing distress was discovered, showed no indications of adverse performance.

The conclusion from the bearing to oil out temperature relationship at the higher speeds is that churning after the oil leaves the bearing is a significant factor.

TABLE 5-1. QCSEE MAIN REDUCTION GEAR - UTW UNIT

DEI QCSEE-12C TEST OPERATION - FINAL CONFIGURATION

Inlet Oil Temperature . . . . 344 - 347°K (160 - 165°F)
Oil Type MIL-L-23699
Oil Density . . . . .967 kg/l (8.05 lb/gal.)

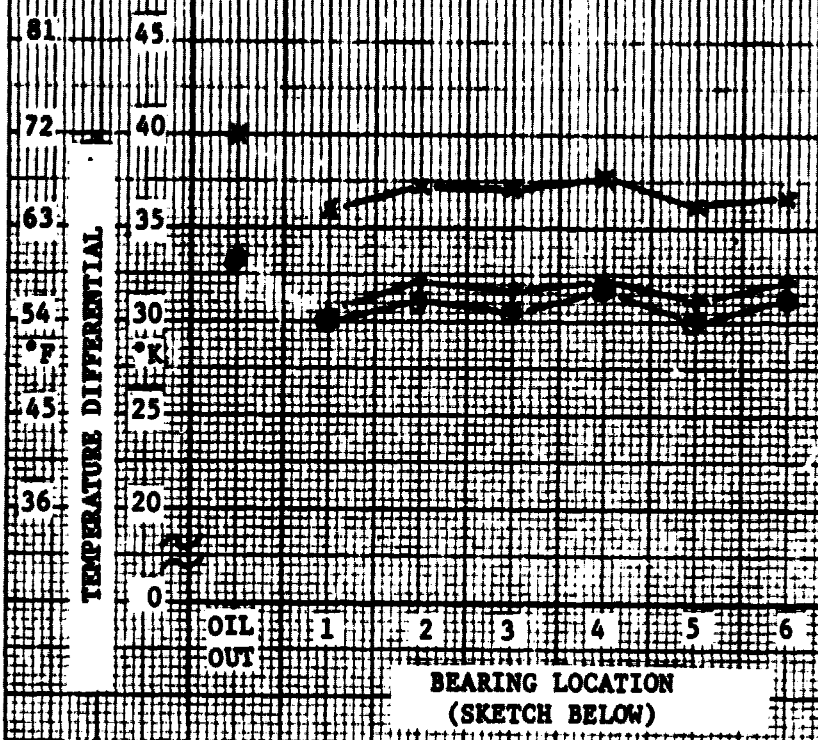
Input Speed rpm	Power		Torque	Oil Flow Rate		Oil Temp. Rise		Brg./Oil ΔT (Avg.)	
	kW	Hp	%	kg/min	lb/min	°K	°F	°K	°F
4005	1499	2009	30	84	184	10	18	11	20
4010	1501	2012	30	67	147	12	21	13	23
5210	1658	2222	25.5	84	184	16	28	15	27
5204	1655	2219	25.5	67	147	18	32	18	32
6270	5744	7700	73.3	84	184	24	43	23	41
7560	5167	6926	54.7	84	184	33	59	30	54
7566	5171	6932	54.7	75	166	34	61	31	56
7560	5167	6926	54.7	84	184	32	58	29	52
7567	9050	12132	95.8	84	184	35	63	32	57

TABLE 5-2. QCSEE MAIN REDUCTION GEAR - UTW UNIT

DEI QCSEE-13 TEST OPERATION (FINAL CONFIGURATION)

Inlet Oil Temperature . . . . 344 - 347°K (160 - 165°F)
Oil Type MIL-L-23699
Oil Density. . . . . .967 kg/l (8.05 lb/gal.)

Input Speed rpm	Power		Torque %	Oil Flow Rate		Oil Temp. Rise		Brg./Oil T (Avg.)	
	kW	Hp		kg/min	lb/min	°K	°F	°K	°F
4000	1508	2022	30.2	67	148	11	20	12	21
5200	1655	2218	25.5	67	148	17	30	17	30
5200	1655	2218	25.5	80	176	16	28	16	28
6270	5744	7700	73.3	80	176	24	44	24	44
7005	4788	6418	54.7	72	159	31	55	29	53
7560	5167	6926	54.7	72	159	34	62	32	57
7560	5167	6926	54.7	79	175	33	60	31	55
7560	9866	13225	104.5	78	171	37	66	34	62
7560	9866	13225	104.5	80	177	37	67	34	62
7781	10155	13612	104.5	80	177	38	69	36	64
7781	12172	16316	125.2	80	177	39	71	37	67
7887	10293	13798	104.5	78	171	39	71	36	64
7996	11165	14967	111.8	83	184	40	72	36	65



SYMBOL	SPEED rpm	TORQUE %	POWER kW	POWER hp	OIL FLOW kg/min	@ °K	lb/min	@ °F
+	7560	54.7	5167	6926	72	@ 347	158	@ 165
⊕	7560	54.7	5167	6926	80	@ 347	176	@ 165
x	7781	125.2	12172	16316	80	@ 346	176	@ 164

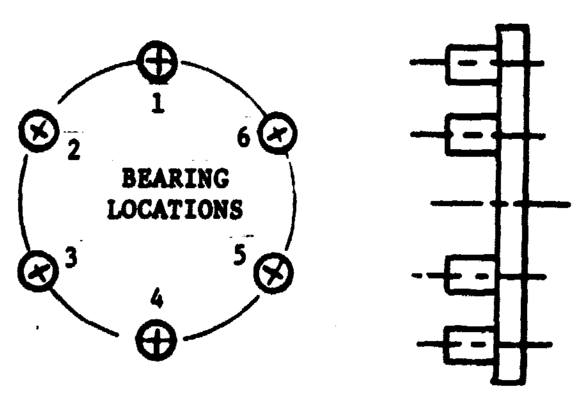


Figure 5.2-6. QCSEE Main Reduction Gear - UTW Test Unit Star Gear Bearing Temperature Rise

5.2.4 Mechanical Efficiency

Mechanical efficiency is the ratio between the power output from the gear set and the power input. The output power is the input power minus friction, oil churning, windage and bearing losses. Three independent sources of power loss data were available in this test program, two indicating the total test rig power loss and the third providing an indication of the individual reduction gear power loss.

The rig input or driving power is calculated from the input torque and input speed indicated by the torquemeter in the input drive. This power loss includes that of the two gear sets and the test rig bearings. The second source of driving power is the electrical power input to the prime mover which includes the prime mover electrical and mechanical inefficiency and the test facility speed increaser losses in addition to the test rig losses. These data are useful primarily for comparing changes in the total power losses from one test to another.

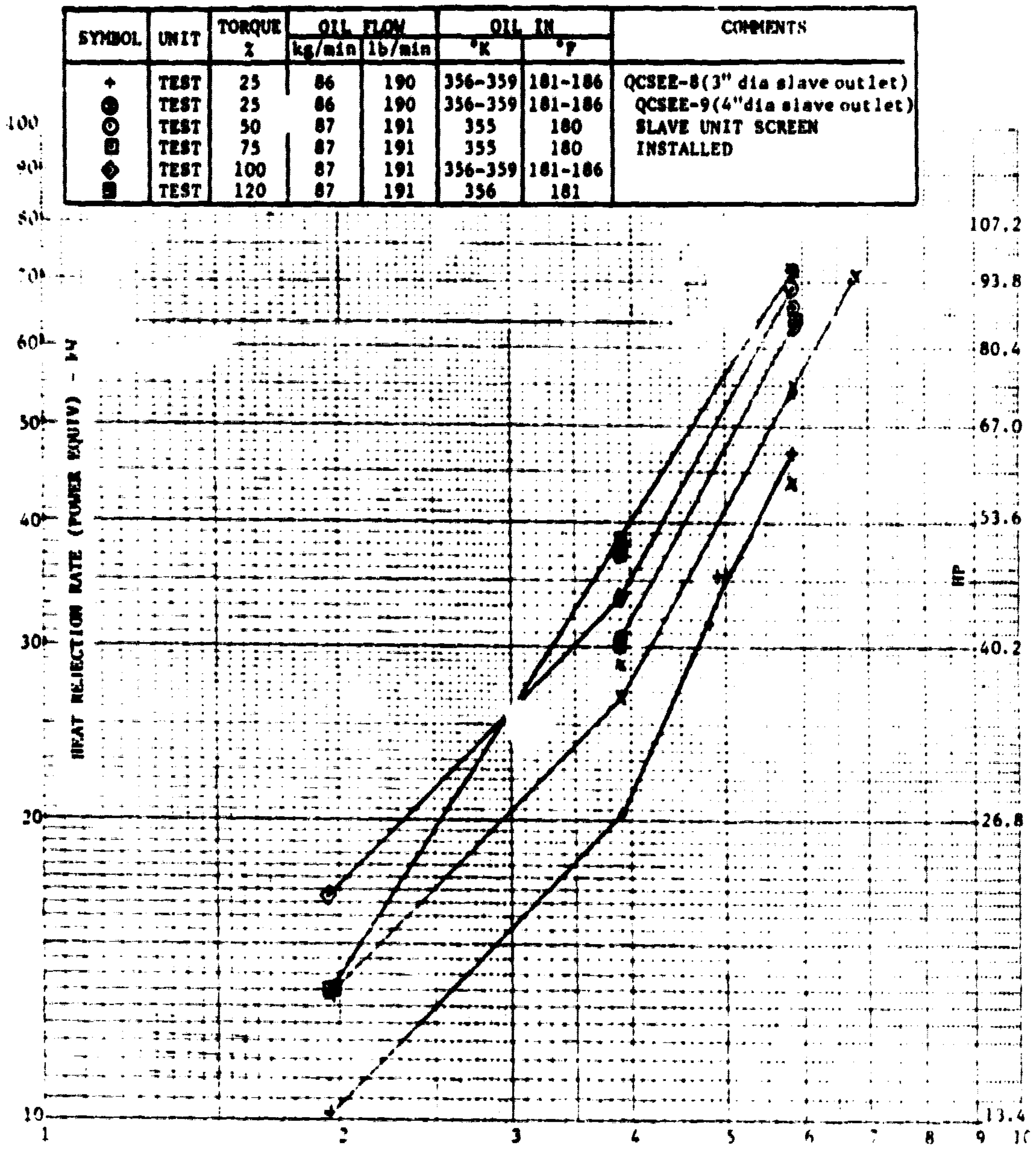
The power loss measurement used for calculating the reduction gear efficiency is the heat rejection to the oil based on the oil flow rate to the individual reduction gear and the temperature differential between entering and exiting oil.

The heat rejection rates versus speed for the several test operating conditions are presented by Figures 5.2-7 through 5.2-11 and Tables 5-3 and 5-4. With the relatively constant oil flow rates through DEI QCSEE-12B test operation, the relationships of the curves are similar to those for the oil temperature rise and the general comments relative to oil temperatures also apply to the heat rejection. Except for Figure 5.2-8, heat rejection data presented are limited to the test reduction gear unit. In Figures 5.2-8 and 5.2-9, the broken lines above approximately 6000 rpm represent the observed speeds and the solid lines represent the actual speeds resulting from the correction of the speed indicator error in this speed range which was later detected.

Throughout all of the tests the slopes of the heat rejection versus speed curves are essentially the same. The highest heat rejection rate was with the 311°K (100°F) inlet oil temperature, DEI QCSEE-10 operation. The difference in heat rejection rates for comparable test operating conditions in DEI QCSEE-9 and DEI QCSEE-11, Figures 5.2-7 and 5.2-10, respectively, is not much greater than the test data accuracy or scatter, even if the effect of any individual rig or gear unit modification could have been identified.

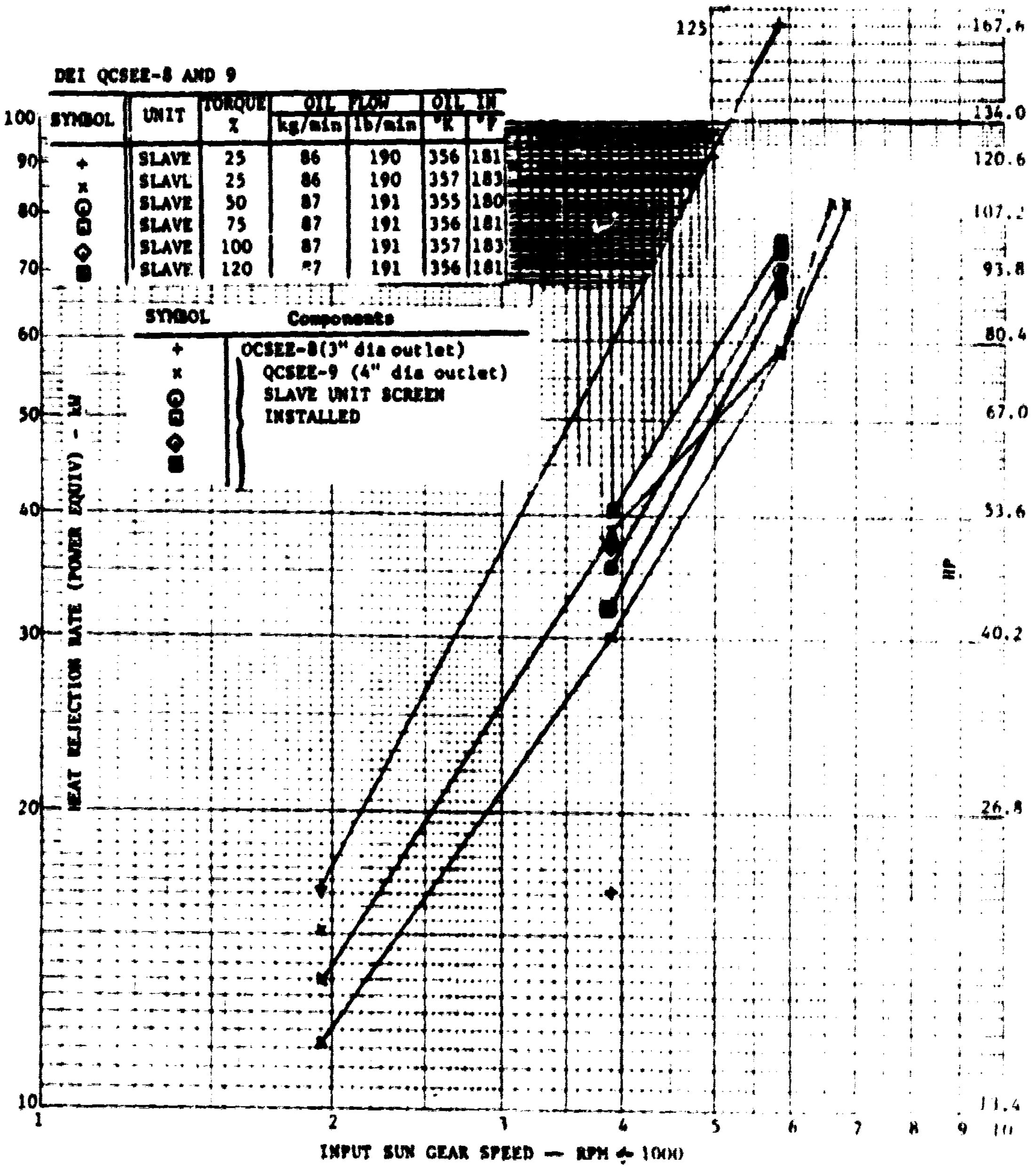
The heat rejection data for DEI QCSEE-12C and QCSEE-13 are presented in Tables 5-3 and 5-4, respectively, since the variety of speed, torque and oil flow rate combinations together with the absence of multiple points with parameter commonality precludes the plotting of curves. It is noted that the heat rejection rate is lowest for the lower oil flow rates with other parameters remaining constant.

DEI QCSEE-8 AND 9



SYMBOL	UNIT	TORQUE %	OIL FLOW kg/min	OIL FLOW lb/min	OIL IN °K	OIL IN °F	COMMENTS
+	TEST	25	86	190	356-359	181-186	QCSEE-8(3" dia slave outlet)
⊕	TEST	25	86	190	356-359	181-186	QCSEE-9(4"dia slave outlet)
⊙	TEST	50	87	191	355	180	SLAVE UNIT SCREEN
⊡	TEST	75	87	191	355	180	INSTALLED
◆	TEST	100	87	191	356-359	181-186	
■	TEST	120	87	191	356	181	

Figure 5.2-7. QCSEE Main Reduction Gear - UTW Test Unit Heat Rejection Rate vs Speed



SYMBOL	UNIT	TORQUE %	OIL FLOW kg/min	OIL FLOW lb/min	OIL IN °K	OIL IN °F
+	SLAVE	25	86	190	356	181
x	SLAVL	25	86	190	357	183
⊙	SLAVE	50	87	191	355	180
⊡	SLAVE	75	87	191	356	181
◇	SLAVE	100	87	191	357	183
■	SLAVE	120	ⁿ7	191	356	181

SYMBOL	Components
+	OCSEE-8(3" dia outlet)
x	QCSEE-9 (4" dia ouclet)
⊙ ⊡ ◇ ■	SLAVE UNIT SCREEN INSTALLED

Figure 5.2-8. QCSEE Main Reduction Gear - UTW Slave Unit Heat Rejection Rate vs Speed

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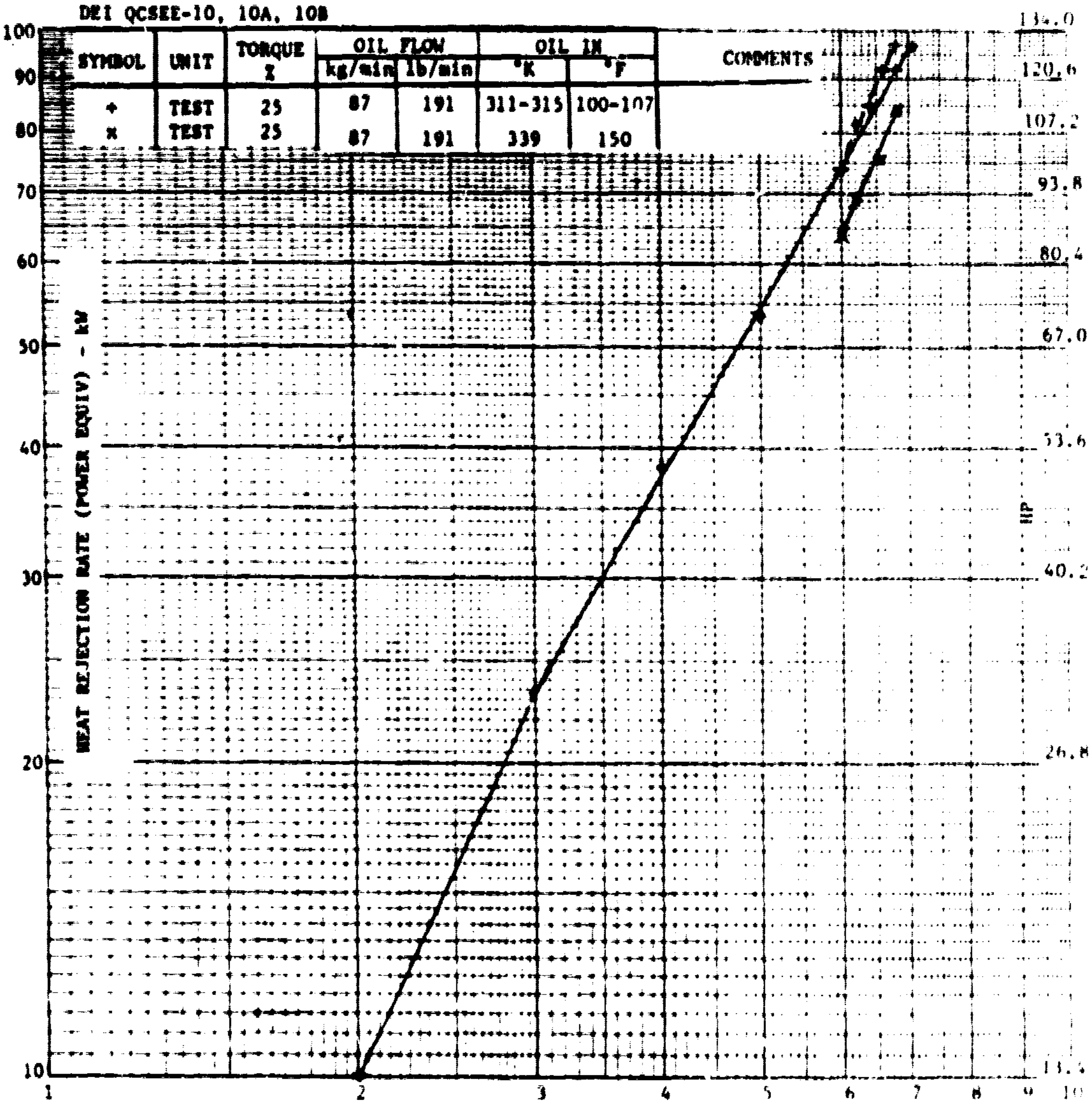
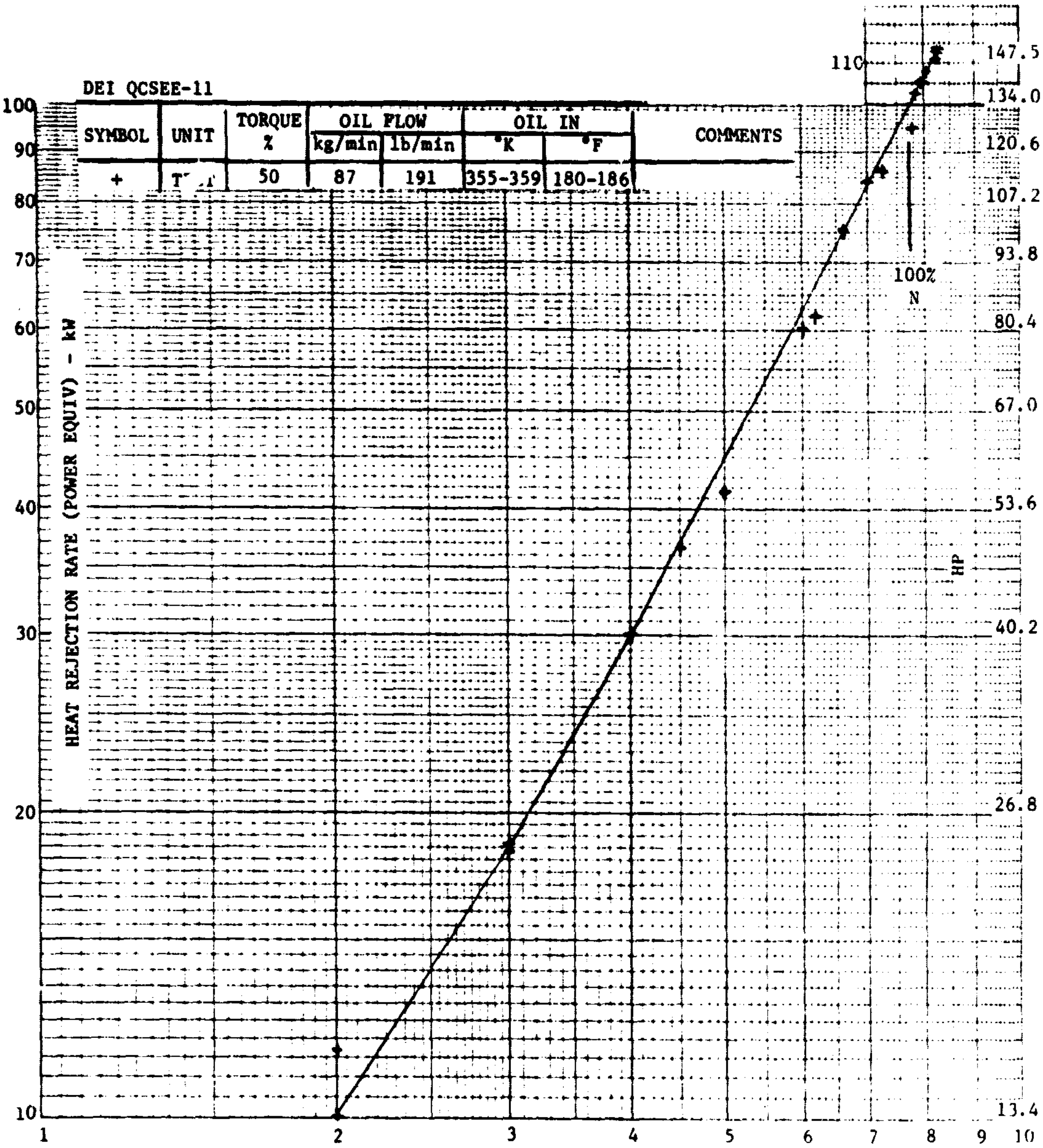


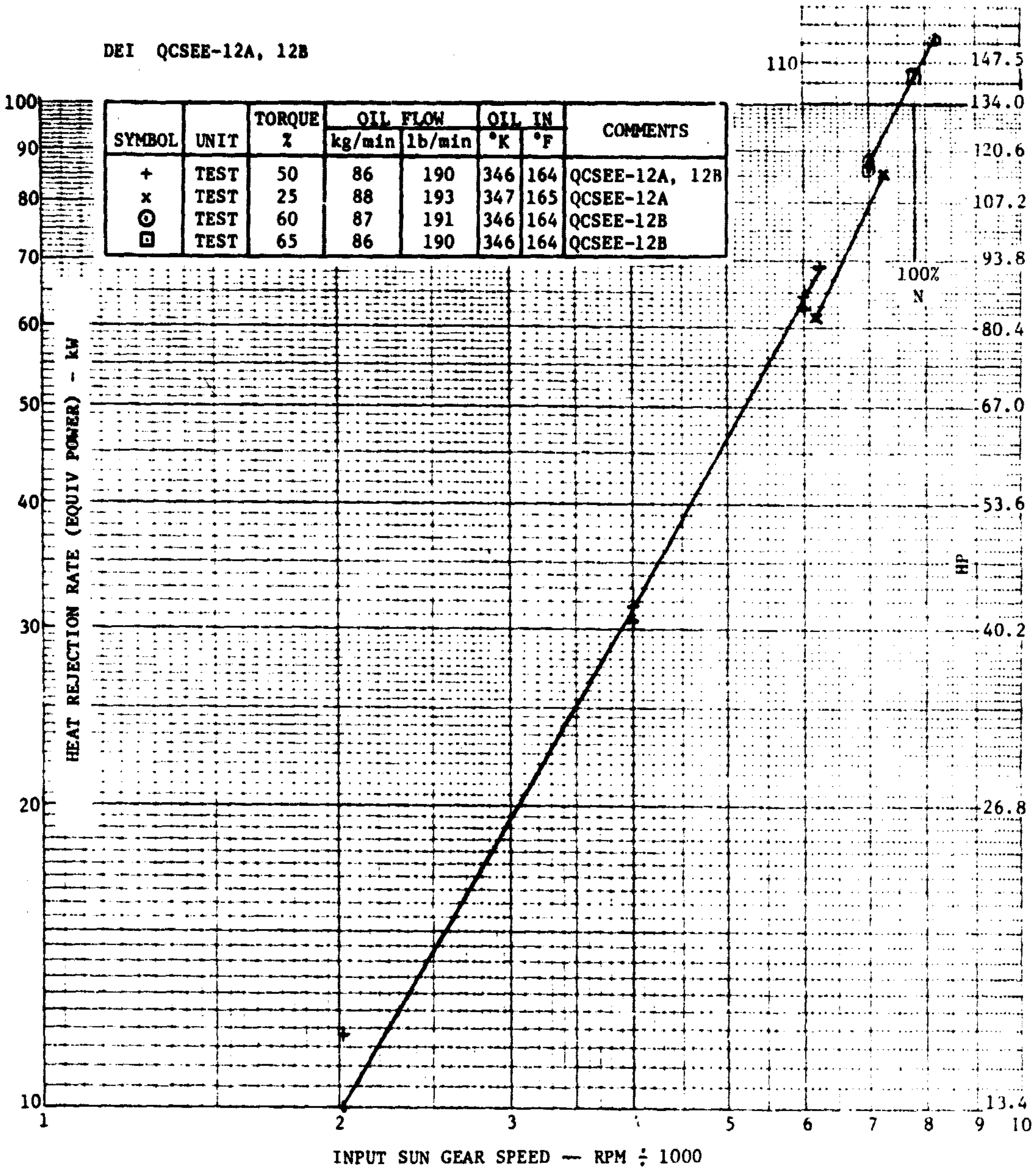
Figure 5.2-9. QCSEE Main Reduction Gear - UTW Test Unit
Heat Rejection Rate vs Speed



DEI QCSEE-11

SYMBOL	UNIT	TORQUE %	OIL FLOW		OIL IN		COMMENTS
			kg/min	lb/min	°K	°F	
+	[illegible]	50	87	191	355-359	180-186	

Figure 5.2-10. QCSEE Main Reduction Gear - UTW Test Unit
Heat Rejection Rate vs Speed



SYMBOL	UNIT	TORQUE %	OIL FLOW kg/min	OIL FLOW lb/min	OIL IN °K	OIL IN °F	COMMENTS
+	TEST	50	86	190	346	164	QCSEE-12A, 12B
x	TEST	25	88	193	347	165	QCSEE-12A
⊙	TEST	60	87	191	346	164	QCSEE-12B
⊡	TEST	65	86	190	346	164	QCSEE-12B

Figure 5.2-11. QCSEE Main Reduction Gear - UTW Test Unit Heat Rejection Rate vs Speed

Efficiencies are also shown in Tables 5-3 and 5-4 for DEI QCSEE-12C and QCSEE-13 operations. Higher efficiencies are indicated for the lower oil flow rates and with the higher torque loads or powers. An efficiency of .991 at the 7781 rpm and 12,172 kW (16,316 hp), 100% speed and 125% torque, operation is indicated.

TABLE 5-3. QCSEE MAIN REDUCTION GEAR - UTW UNIT

DEI QCSEE-12C TEST OPERATION

HEAT REJECTION AND EFFICIENCY

Inlet Oil Temperature . . . . 344 - 347°K (160 - 166°F)
Oil Type MIL-L-23699
Oil Density . . . . .967 kg/l (8.05 lb/gal.)

Input Speed	Power		Torque	Oil Flow Rate		Heat Rej. Rate		Eff.
rpm	kW	Hp	%	kg/min	lb/min	kW	Hp	
4010	1501	2012	30	67	147	27	36	.982
4005	1499	2009	30	84	184	29	39	.981
5204	1655	2219	25.5	67	147	41	55	.975
5210	1658	2222	25.5	84	184	46	61	.973
6270	5744	7700	73.3	84	184	69	93	.988
7566	5171	6932	54.7	75	166	89	119	.983
7560	5167	6926	54.7	84	184	95	128	.982
7560	5167	6926	54.7	84	184	94	126	.982
7567	9050	12132	95.8	84	184	102	137	.989

TABLE 5-4. QCSEE MAIN REDUCTION GEAR - UTW UNIT

DEI QCSEE-13 TEST OPERATION (FINAL CONFIGURATION)

HEAT REJECTION AND EFFICIENCY

Inlet Oil Temperature . . . . 344 - 347°K (160 - 166°F)
Oil Type MIL-L-23699
Oil Density . . . . .967 kg/l (8.05 lb/gal.)

Input Speed	Power		Torque	Oil Flow Rate		Heat Rej. Rate		Eff.
rpm	kW	Hp	%	kg/min	lb/min	kW	Hp	
4000	1508	2022	30.2	67	148	25	33	.984
4010	1512	2027	30.2	80	176	28	37	.982
5200	1655	2218	25.5	67	148	39	52	.977
5200	1655	2218	25.5	80	176	45	60	.973
6270	5744	7700	73.3	80	176	68	91	.988
7005	4788	6418	54.7	72	159	77	103	.984
7560	5167	6926	54.7	72	159	87	116	.983
7560	5167	6926	54.7	79	175	93	124	.982
7560	9866	13225	104.5	78	171	99	133	.990
7560	9866	13225	104.5	80	177	104	140	.989
7781	10155	13612	104.5	80	177	107	144	.989
7781	12172	16316	125.2	80	177	110	148	.991
7887	10293	13798	104.5	78	171	107	143	.990
7996	11165	14967	111.8	83	184	116	156	.990

Heat rejection rates and efficiencies are shown in Tables 5-5 and 5-6 for representative operations at 75% and 100% speed, respectively, throughout the test program. These data are also plotted in Figure 5.2-12. The efficiency at the maximum test operation speed of 8250 rpm at 50% torque, 6906 horsepower, was .978. The heat rejection data shown in Tables 5-5 and 5-6 are for actual test points where available, otherwise, the data were obtained by extrapolation and extension of the curves in Figures 5.2-7, 5.2-9, 5.2-10 and 5.2-11.

The basic conclusion from the heat rejection and efficiency data is that oil churning is the major contributor to the power loss or reduced efficiency and overall reduction gear efficiency increases with increased torque up to 125% design torque.

TABLE 5-5. QCSEE MAIN REDUCTION GEAR - UTW UNIT

HEAT REJECTION AND EFFICIENCY
AT 5836 RPM (75% SPEED)

DEI QCSEE No.	Torque %	Power		Oil In				Heat Rej.		Eff.	Sym. Fig. 5.2-12
				Flow		Temp					
		kW	HP	kg/min	lb/min	°K	°F	kW	Hp		
Ref.	100	7284	9764	-	-	-	-	-	-	-	-
9	25	1821	2441	86	190	358	185	55	74	.970	+
	50	3642	4882	88	193	355	181	66	88	.982	+
	75	5463	7323	86	190	357	183	64	85	.988	+
	100	7284	9764	87	191	358	185	69	92	.991	+
	120	8741	11717	87	191	356	182	72	97	.992	+
10	25	1821	2441	87	191	312	103	71	95	.961	⊗
	25	1821	2441	87	191	339	150	61	82	.967	x
11	50	3642	4882	87	191	356	181	60	80	.984	⊙
12A	25	1821	2441	88	193	347	166	55	74	.970	◈
12A	50	3642	4882	87	191	347	165	61	82	.983	◈
12B	60	4370	5858	87	191	345	162	64	86	.985	◈
12B	65	4735	6347	87	191	345	162	64	86	.986	◈

QCSEE-9 Data are from actual test points. Other data are extrapolated from the heat rejection curves.

TABLE 5-6. QCSEE MAIN REDUCTION GEAR - UTW UNIT

HEAT REJECTION AND EFFICIENCY
AT 7782 RPM (100% SPEED)

DEI QCSEE No.	Torque %	Power		Oil In				Heat Rej.		Eff.	Sym. Fig. 5.2-12
				Flow		Temp					
		kW	Hp	kg/min	lb/min	°K	°F	kW	Hp		
Ref.	100	9712	13019	-	-	-	-	-	-	-	-
9	25	2428	3255	86	190	356	185	90	121	.963	+
	50	4856	6510	88	193	355	181	105	141	.978	+
	75	7284	9764	86	190	355	181	105	141	.986	+
	100	9712	13019	87	191	356	182	115	154	.988	+
	120	11654	15623	87	192	356	182	111	149	.990	+
10	25	2428	3255	87	191	311	106	113	151	.953	●
	25	2428	3255	87	191	339	151	109	146	.955	x
11	50	4856	6510	88	193	355	180	100	134	.979	⊙
12A	25	2428	3255	88	193	347	165	99	133	.959	⟐
12A	50	4856	6510	86	190	346	163	101	135	.979	⟐
12B	60	5827	7811	87	191	346	163	106	142	.982	⟐
12B	65	6313	8462	86	190	346	163	106	142	.983	⟐
13	104.5	10155	13602	80	176	344	164	107	143	.989	⊞
	125.2	12172	16316	80	177	344	163	110	148	.991	◈

QCSEE-12B and 13 data are from actual test points. Other data are extrapolated from the heat rejection curves.

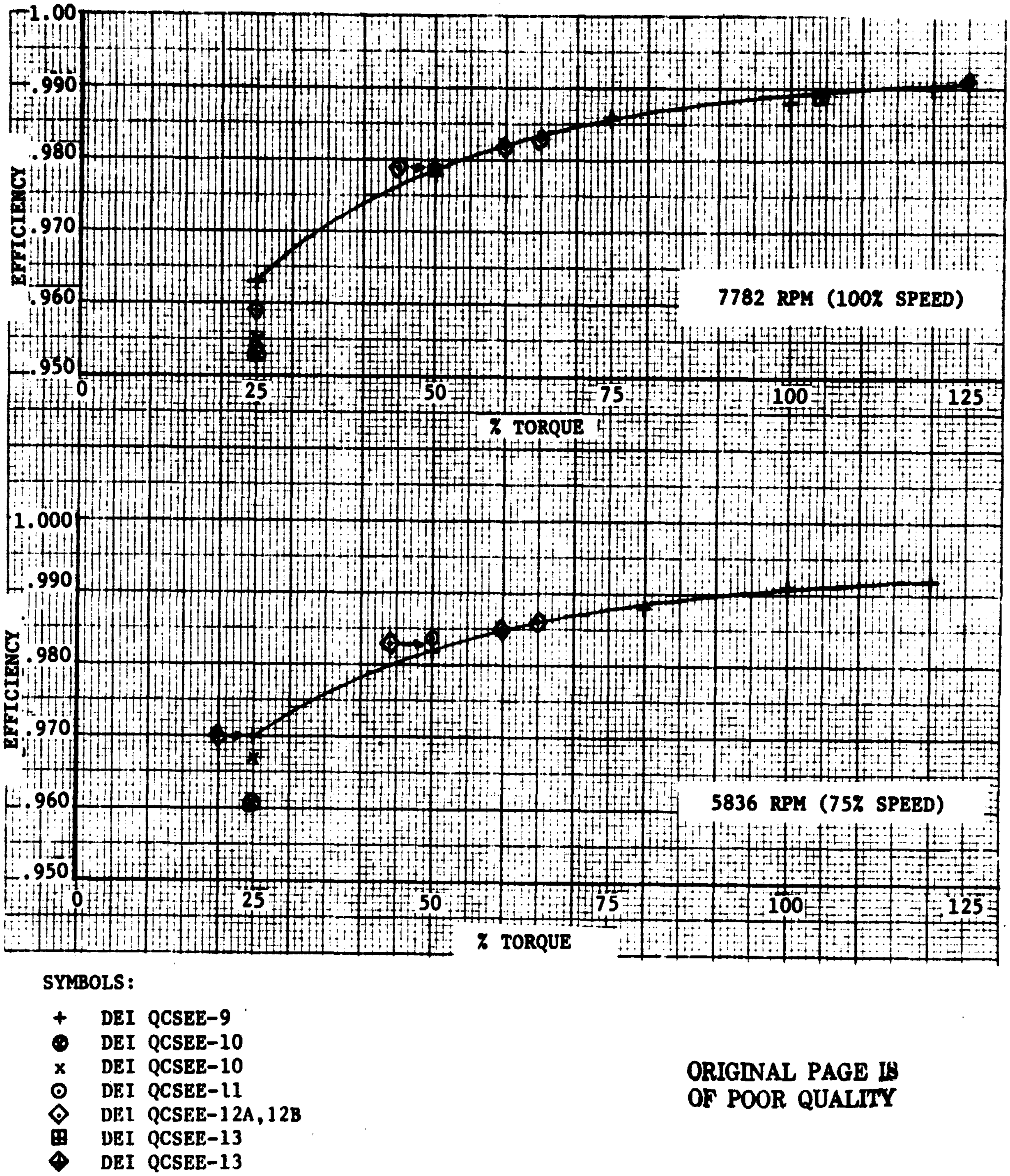


Figure 5.2-12. QCSEE Main Reduction Gear - UTW Test Unit Efficiency Vs Torque

5.2.5 Vibratory Characteristics

During the back-to-back testing of the QCSEE under the wing main reduction gear several modifications of the test setup and vibration monitoring system were made.

The original test setup consisted of a dynamometer driving a 1:3.3 speed increaser which drives the back-to-back gear units in the test rig through an unsupported torquemeter shaft. Figure 4.5-2 shows the vibration monitoring instrumentation used for this initial phase of testing. The rig was operated up to fifty (50) percent design torque and the input speed through 8,000 rpm, DEI QCSEE-11.

The facility gearbox has a horizontal mount resonance at 5350 Hz which was excited by the input shaft at 5350 rpm. The peak amplitude of ±2.3 mils was not evident on the vibration monitoring instrumentation located on the slave and test gear unit ends of the test rig. Figure 5.2-13 shows the vibration vertical and horizontal amplitudes versus speed for test rig and facility speed increaser.

Figure 5.2-13 also shows the primary vibration response being in the horizontal direction for both the slave and test gear ends of the rig. The two peaks shown are due to excitation of the test rig support structure horizontal natural frequency;

a. First order of the input shaft near 4000 input rpm.

b. First order of the output shaft at 7500 input rpm.

The vertical natural frequency of the gearbox support structure is excited by the input shaft near 6000 input rpm, Figure 5.2-13. Amplitudes are increasing at 8000 rpm.

The fore and aft translational response is similar to the horizontal response.

Experimental checks of the support structure confirmed the two natural frequencies;

Horizontal 60 Hz and Vertical 90 to 100 Hz.

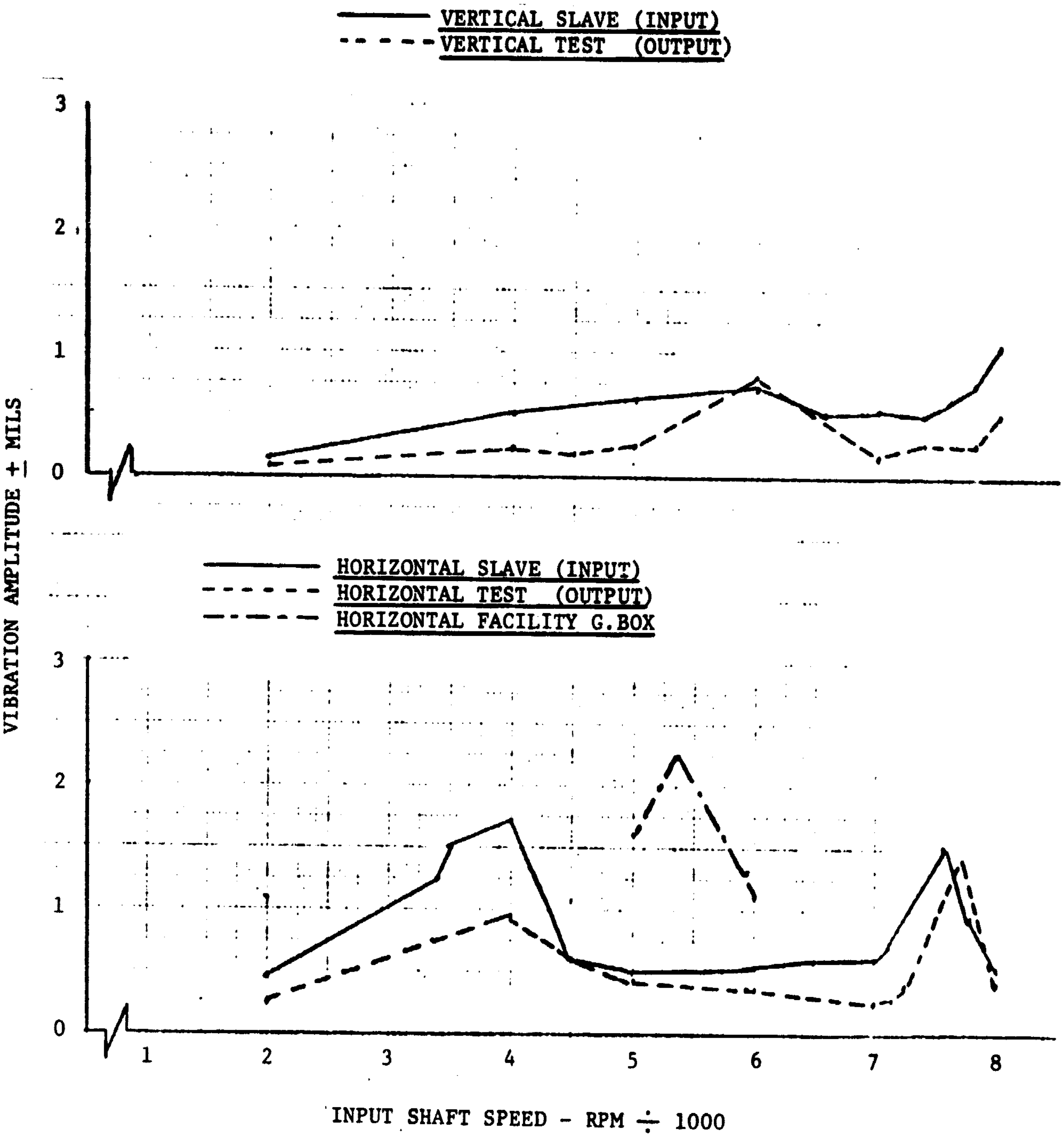


Figure 5.2-13. QCSEE Main Reduction Gear - UTW Vibration Amplitude Vs Speed (DEI QCSEE-11)

50% TORQUE

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After DEI QCSEE-11 test operation, certain wear characteristics were observed on the gear teeth. The torquemeter instrumentation also showed signs of malfunctioning. A pedestal support for the torquemeter was installed and shaft proximity pickups were added to determine shaft radial motions.

The horizontal translational pickups still showed the peak response near 4000 rpm due to first order input shaft excitation. The response between 7500 to 8000 rpm was sharply reduced, Figure 5.2-14.

Figure 5.2-14 shows that the vertical pickups response is fairly flat throughout the speed range. This data was obtained from oscillograph records which represent the total amplitude which is a complex signal made up of several frequencies. At 6750 rpm, the response is primarily one frequency, twice input shaft order. This characteristic was not too evident during the initial test runs.

A vertical translational pickup was installed on the torquemeter pedestal. Figure 5.2-14 shows the results of initial tests in which the natural frequency of pedestal (134 Hz) is excited by the first order input shaft at 8000 rpm. A second curve shows how adding a 50 pound weight, reduces the natural frequency to 50 Hz and eliminates the peak at 8000 rpm.

The proximity pickups indicated several peak responses, Figure 5.2-15.

Position	RPM	Excitation
Slave Box Horizontal	6950	Input Speed
Mid-Shaft Horizontal	3500	Input Speed
Mid-Shaft Horizontal	6000	Twice Input Speed
Mid-Shaft Horizontal	6800	Twice Input Speed
Mid-Shaft Horizontal	7000	Input Speed

The added weight eliminated the first order input shaft response near 7000 rpm.

The twice input shaft response at 6800 is 227 Hz and matches the natural frequency of the proximity probe itself.

Of the five peaks noted on the proximity pickups, two were eliminated by modifying the pedestal, one is associated with the probe natural frequency and the other two occur at speeds (3500 and 6000 rpm) at which gear wear is not suspected.

Inspection of the gear teeth during DEI QCSEE-12 series test operations continued to show signs of undesirable wear patterns. Data from neither the shaft proximity pickup nor the housing vibration pickups could be related to the gear motions indicated by the wear patterns. Additional instrumentation was installed in the test unit end of the test rig to further identify the gear motions. This instrumentation included two proximity pickups near the aft face of the upper star gear and vertical and horizontal accelerometers on the star gear support as shown by Figure 5.2-16.

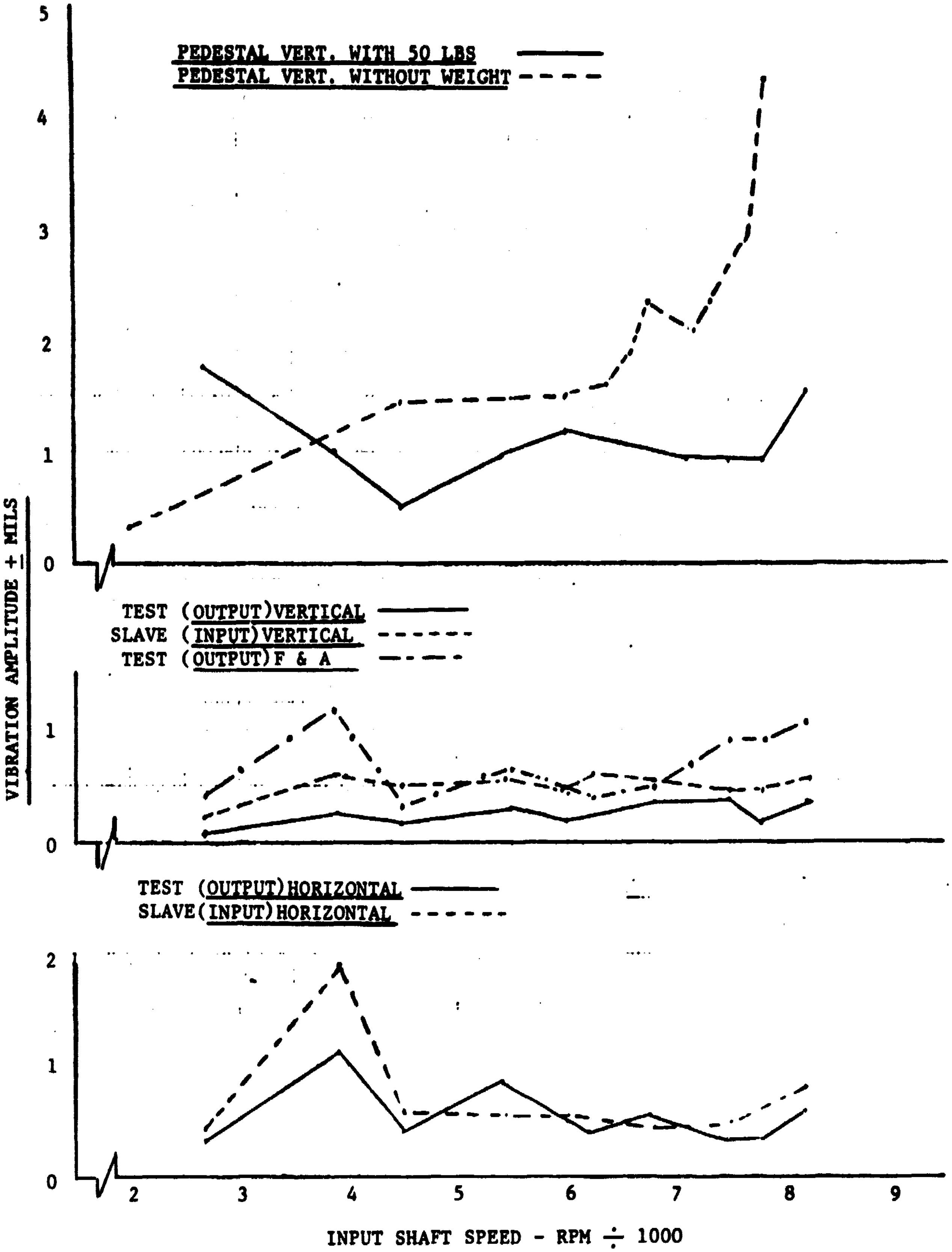

Figure 5.2-14. QCSEE Main Reduction Gear - UTW Vibratory Amplitude Vs Speed (DEI QCSEE-11) Translational Pickup

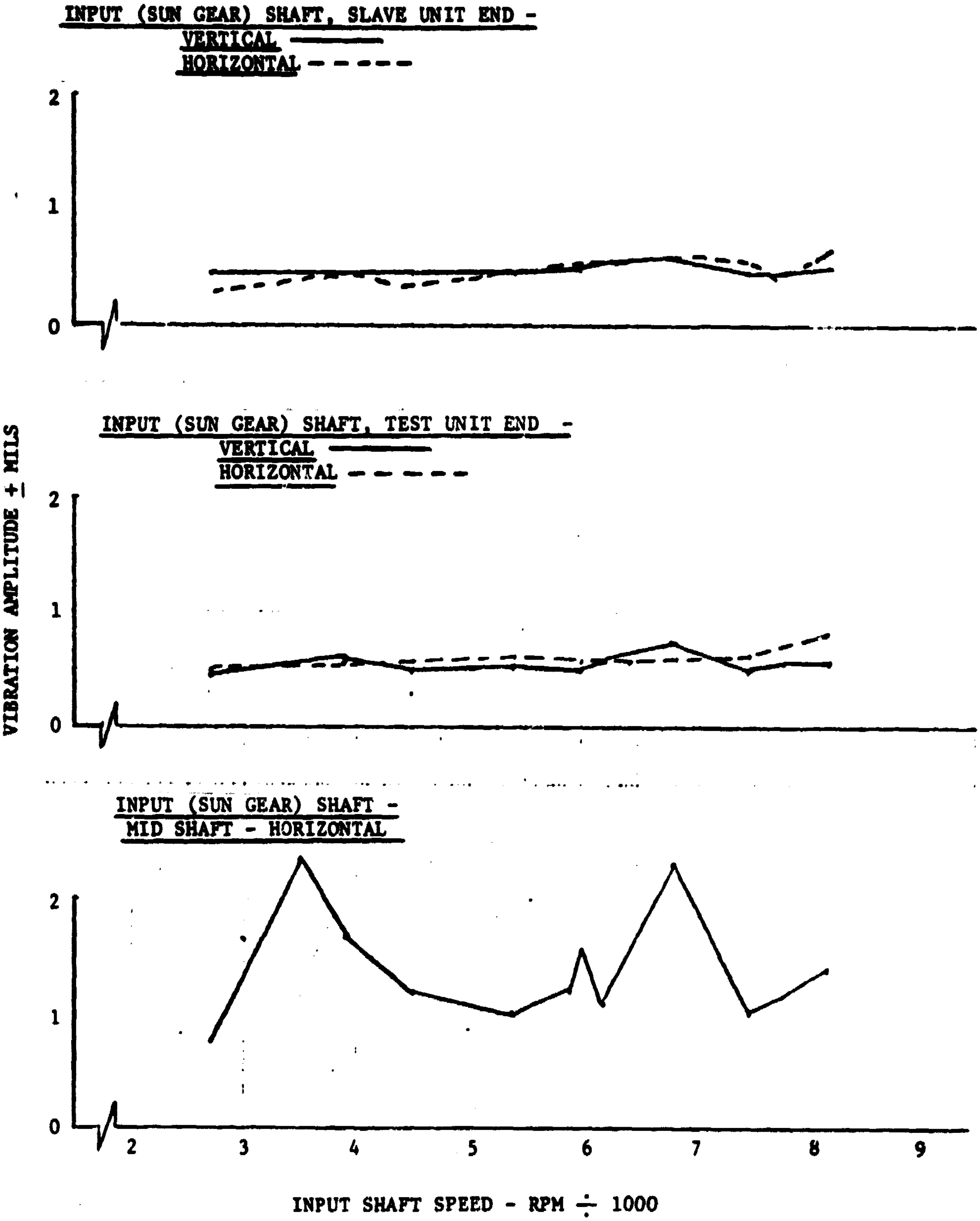

Figure 5.2-15. QCSEE Main Reduction Gear - UTW Vibratory Amplitude Vs Speed (DEI QCSEE-12) Proximity Pickup

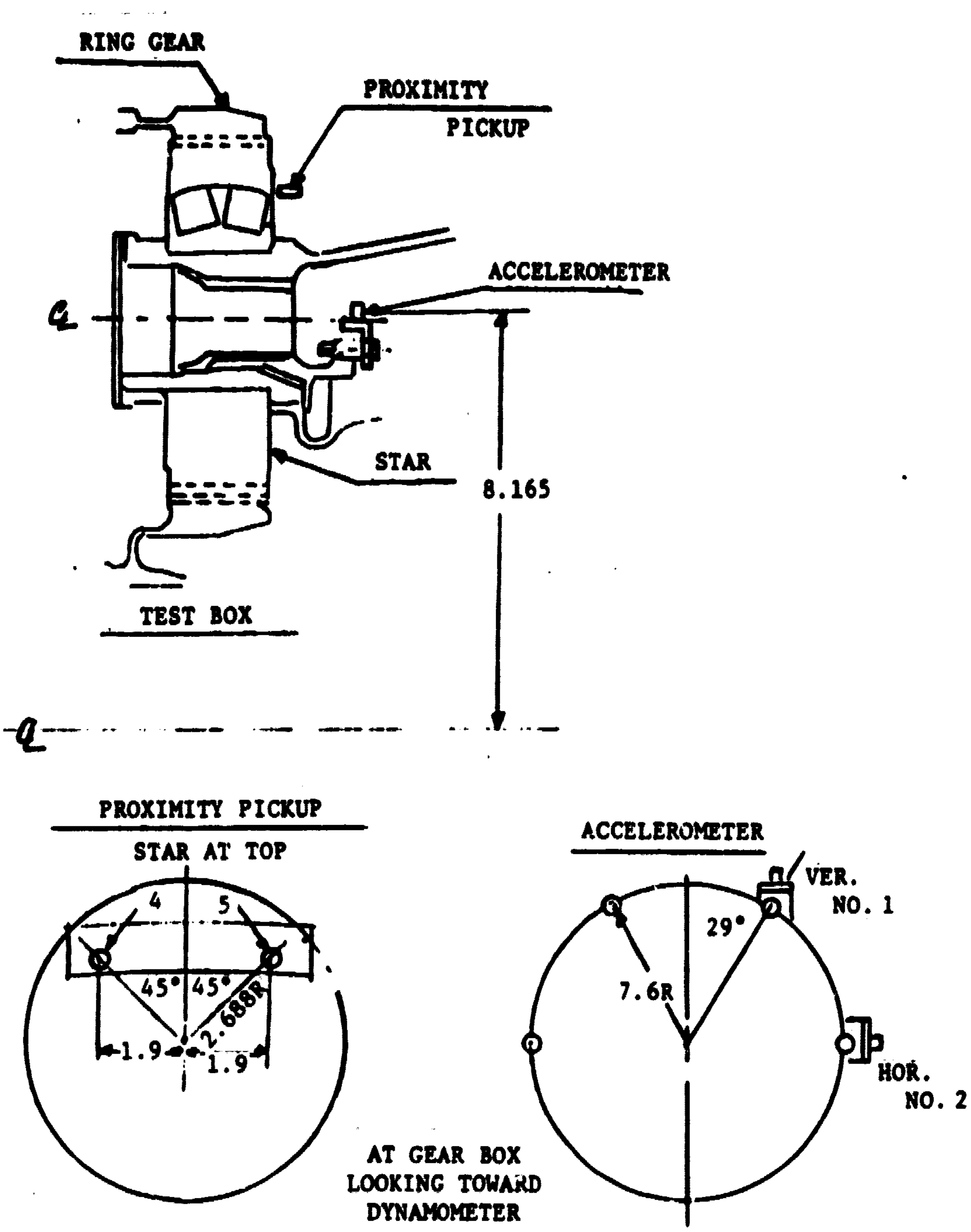

Figure 5.2-16. QCSEE Main Reduction Gear - UTW Proximity and Accelerometer Locations (DEI QCSEE-13)

The axial motion of the star gear is shown on Figure 5.2-17 as a function of input sun gear speed. The actual measured motion was multiplied by 1.816 to obtain an estimate of the axial motion at the pitch line of the gear tooth. A peak value of 14.9 total mils was recorded at 7560 rpm, 5640 kW (6930 hp). The 1.816 factor is the ratio of the vertical distances of the proximity pickup location and the star gear/ring gear mesh point from the center of the star gear.

A typical oscillograph trace of three proximity pickups at 7560 rpm, 5640 kW (6930 hp) is shown on Figure 5.2-18. The results of a wave analysis of the response are plotted on Figure 5.2-19. It must be noted that

a. The scale factors for the traces are <u>not</u> the same. The actual displacement values are noted on the trace.

b. Careful examination of the mid-shaft proximity trace (No. 3) shows that it is <u>not</u> similar to the star gear motion.

The major response at the peak amplitude is due to first order of the star gear. This particular component increases by a factor of 5 between 6300 and 7560 rpm. The frequency at the peak is 175 Hz. Maximum measured amplitude of "rocking" occurs once each star gear revolution.

The following table shows the effect of power on the major components of the axial motion of the star gear at 7560 rpm. Figure 5.2-19 shows the data for the lower power at 7560 rpm.

	Mils Displacement	
Component	5170 kW (6930 Hp)	9850 kW (13200 Hp)
Ring	5.2	2.0
Sun	5.2	4.2
Star	11.2	4.3
1.25 Star	4.6	7.5
Total	14.2	9.8

A second major response is at approximately 1.25 star speed (ring plus star order is 1.3 star speed).

Figure 5.2-20 shows a typical component analysis readout. Amplitude is in a log format, not linear. All component frequency data in this report comes from this type of analysis.

Accelerometer data was primarily used to evaluate vibration that occurred above 1000 Hz. Figure 5.2-21 shows the accelerometer data recorded during the last phase of testing. The major response is at 7560 rpm with two significant components:

1500 Hz	30 Gs
2950 Hz	25 Gs

These two components are one-sixth and one-third the gear meshing frequency.

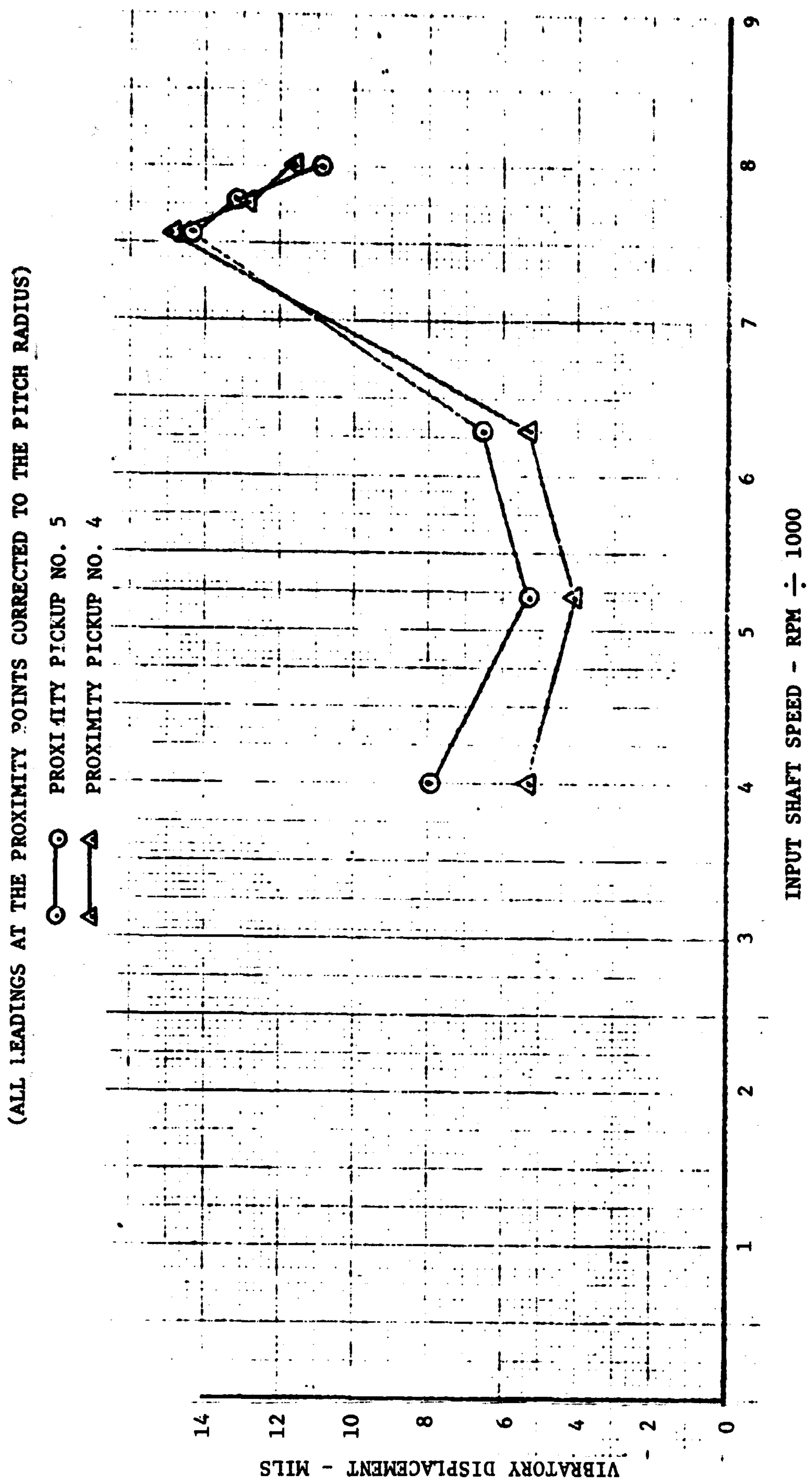

Figure 5.2-17. Reduction Gear Back-To-Back Test - UTW Vibratory Displacement of the Star Gear Vs Speed

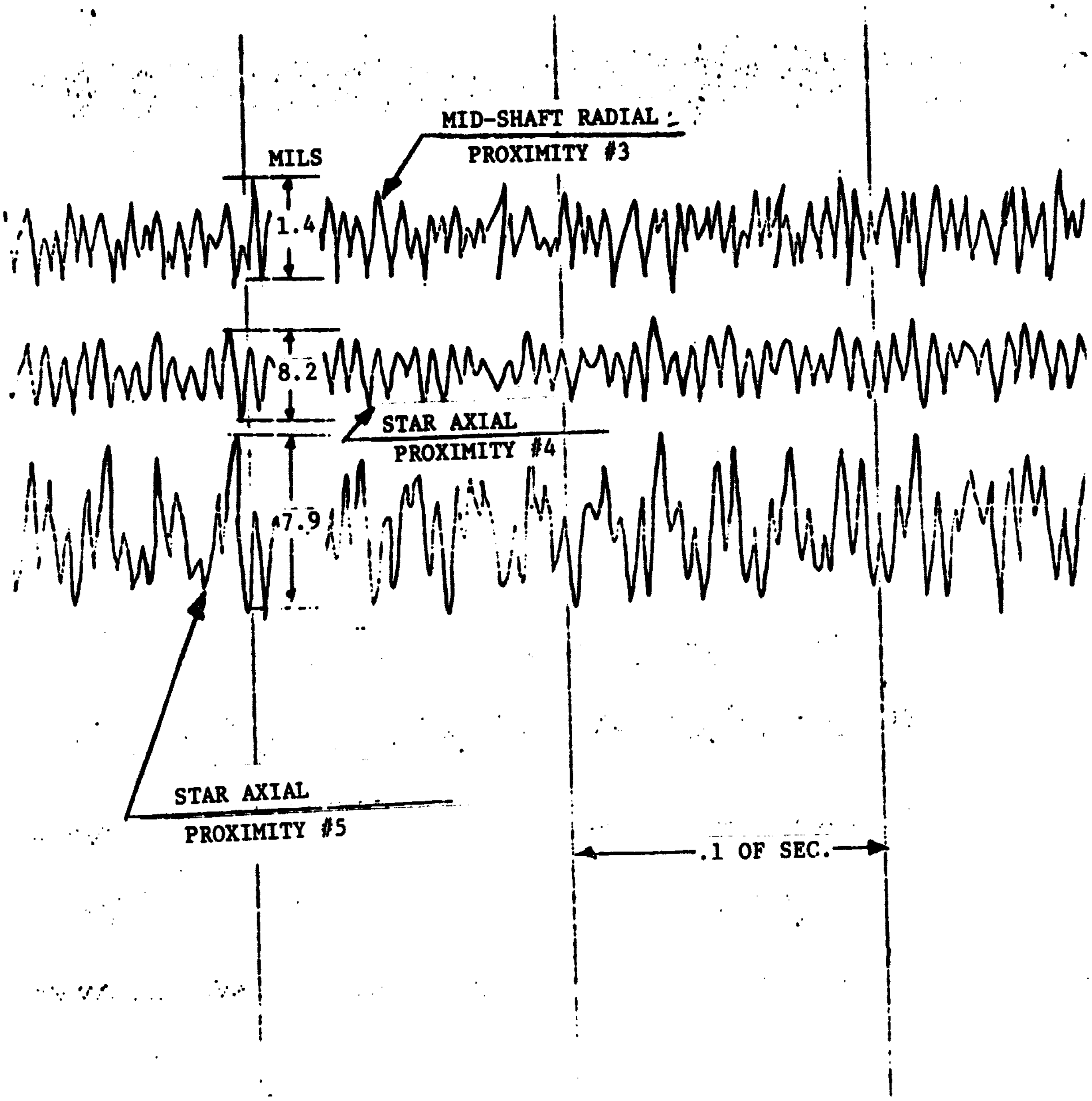

Figure 5.2-18. QCSEE Main Reduction Gear - UTW
Typical Trace of Proximity Probes at 7560 RPM, 50% Torque

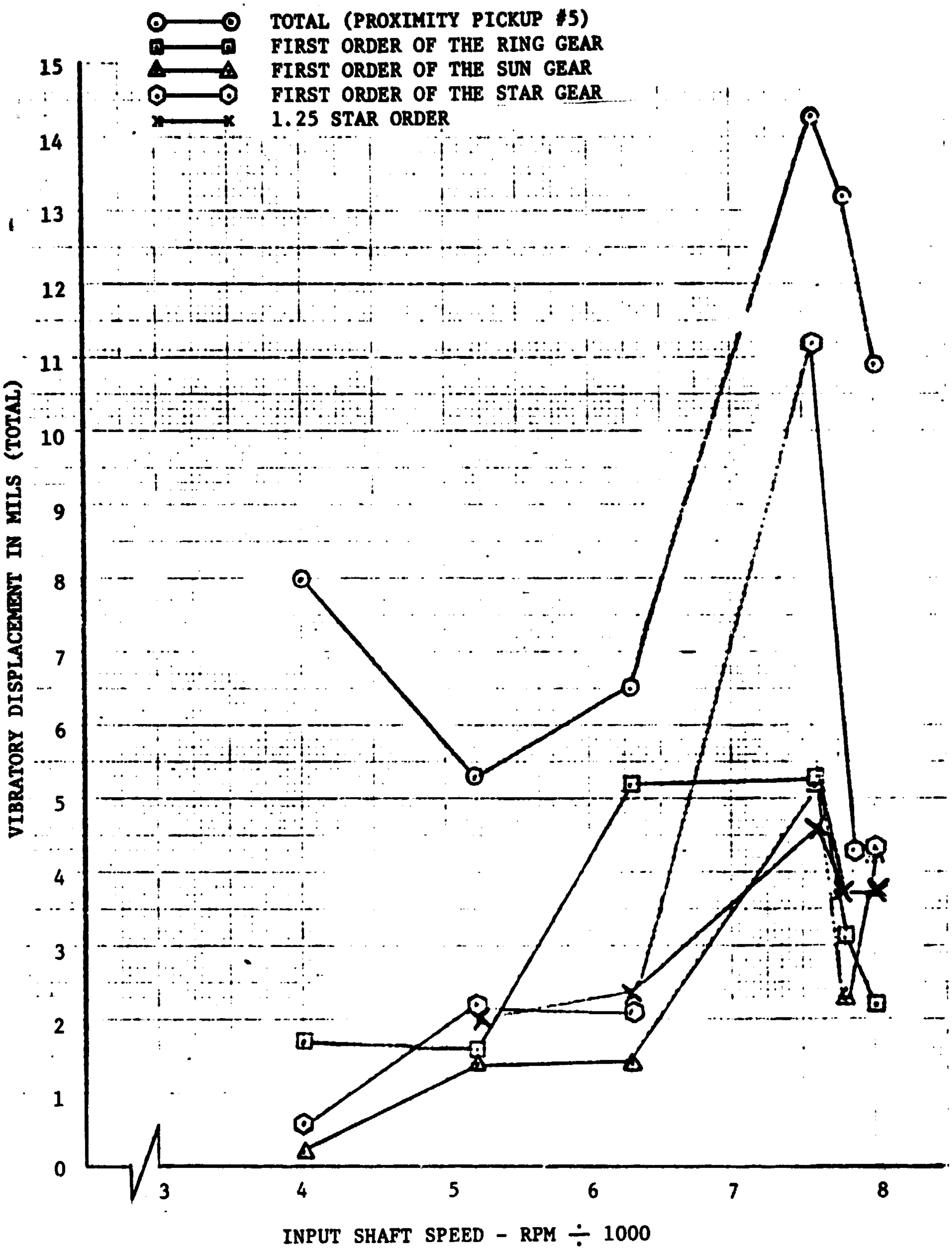

Figure 5.2-19. QCSEE Main Reduction Gear Test - UTW Vibratory Displacement of the Star Vs RPM @ 50% Torque

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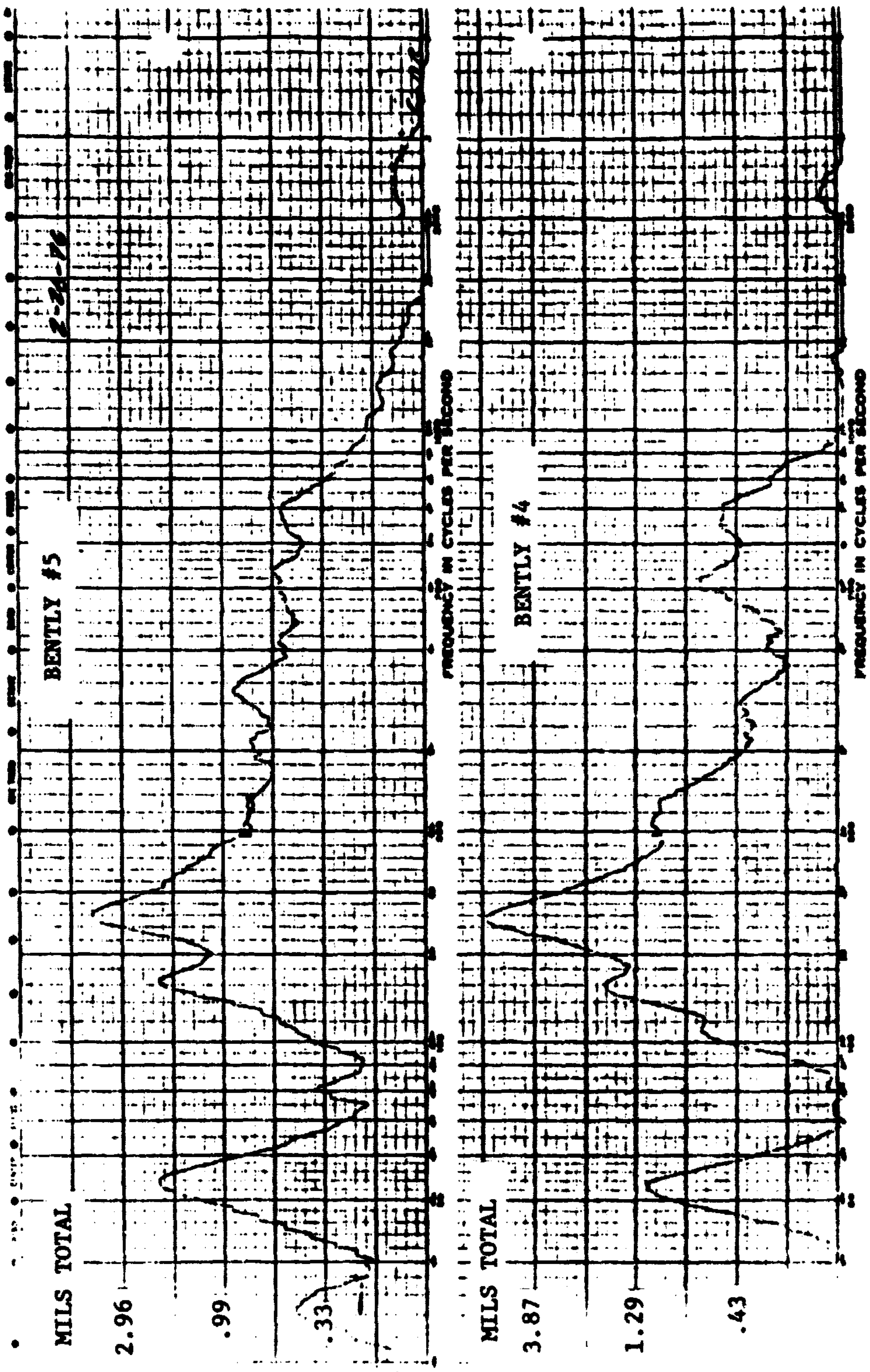

7560 RPM - 6930 HP (50% TORQUE)

Figure 5.2-20 QCSEE Main Reduction Gear -UTW
Star Motion on Graphic Recorder

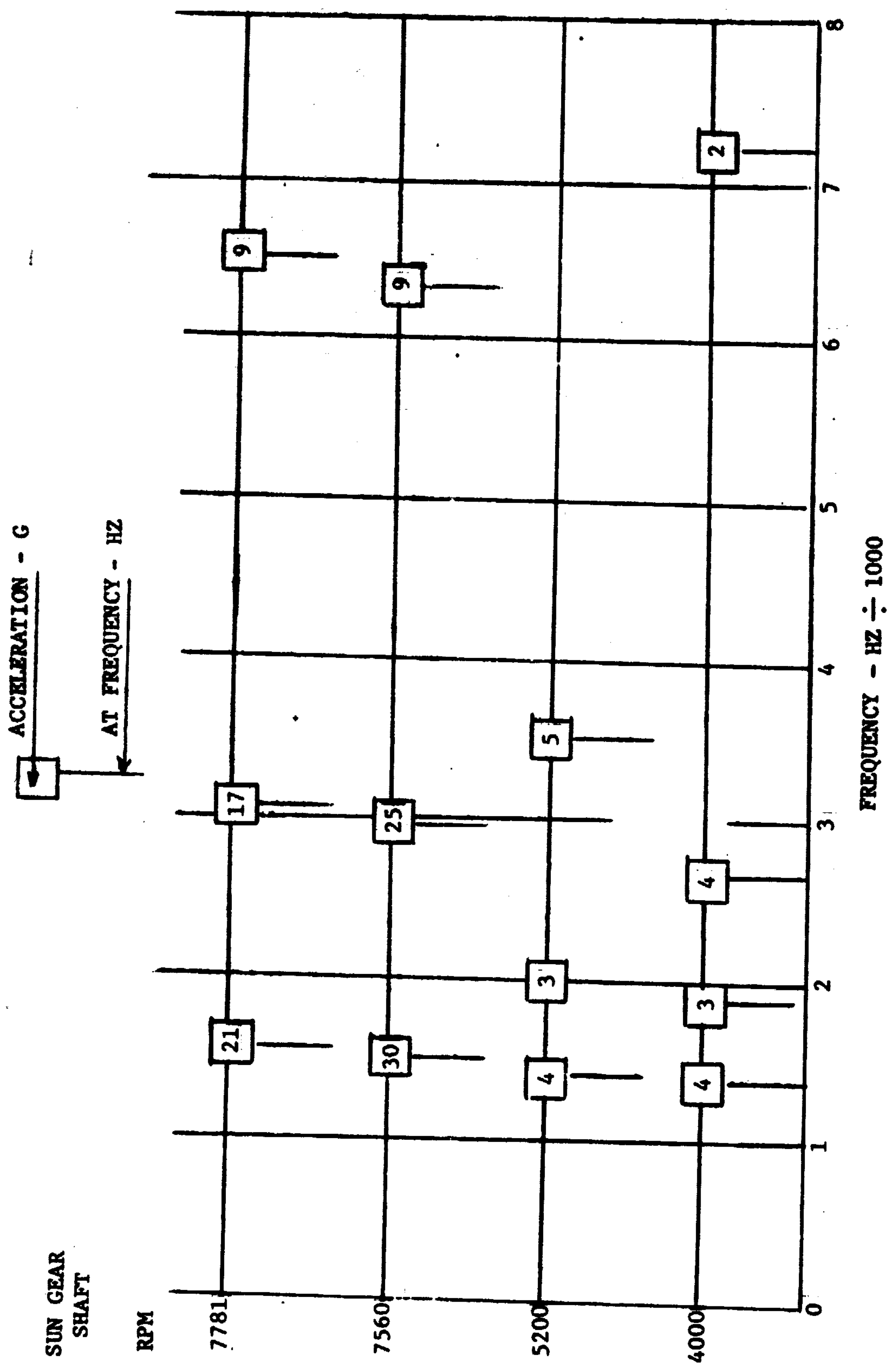

Figure 5.2-21. QCSEE Main Reduction Gear - UTW Acceleration Vs RPM

The meshing frequency component response is much larger at 4000 rpm than at higher speeds.

Experimental natural frequency checks were made of the sun gear prior to assembly. Curtiss-Wright tests made by striking the freely supported gear and analyzing the "sound" response provided the following data.

Mode	Hz
2 Diameter	1050
3 Diameter	2410
4 Diameter	4500
Not Identified	300

The ring gear was calculated to have the following natural frequencies:

Mode	Hz
2 Diameter	75
3 Diameter	210
4 Diameter	404
5 Diameter	653
6 Diameter	958

The flexibility of the flex coupling was calculated as 2.76 x 10^3 kg/cm (1.54 x 10^5 lb/in.) with respect to the sun gear vertical motion. It is possible that a natural frequency associated with the coupling may be in the suspected frequency range. Figure 5.2-22 is a sketch of the coupling and sun gear.

Since the sun gear and flex coupling rotate at input speed and the star gear rotates at 1.3654 input speed, the actual mode shape of the sun gear at 7560 rpm is rather complex because the star gear wobble is at star gear speed.

Analysis of the vibration data and observations resulted in the following conclusions:

a. Wear noted on the gears in early tests came about from operation at speeds of approximately 7000 rpm and above.

b. Translational pickups on the outside of the test rig and proximity pickups on the input or sun gear shaft do not show a significant increase to any particular phenomenon in the suspected speed range. This leads to the conclusion that neither housing (support structure) natural frequencies nor input shaft natural frequencies caused the observed gear wear.

c. Measurements of the star gear axial motion (wobble) show a sharp increase in motion above 7000 rpm input shaft speed. This wobble is most likely the cause of the gear wear. The motion decreases as the transmitted torque increases.

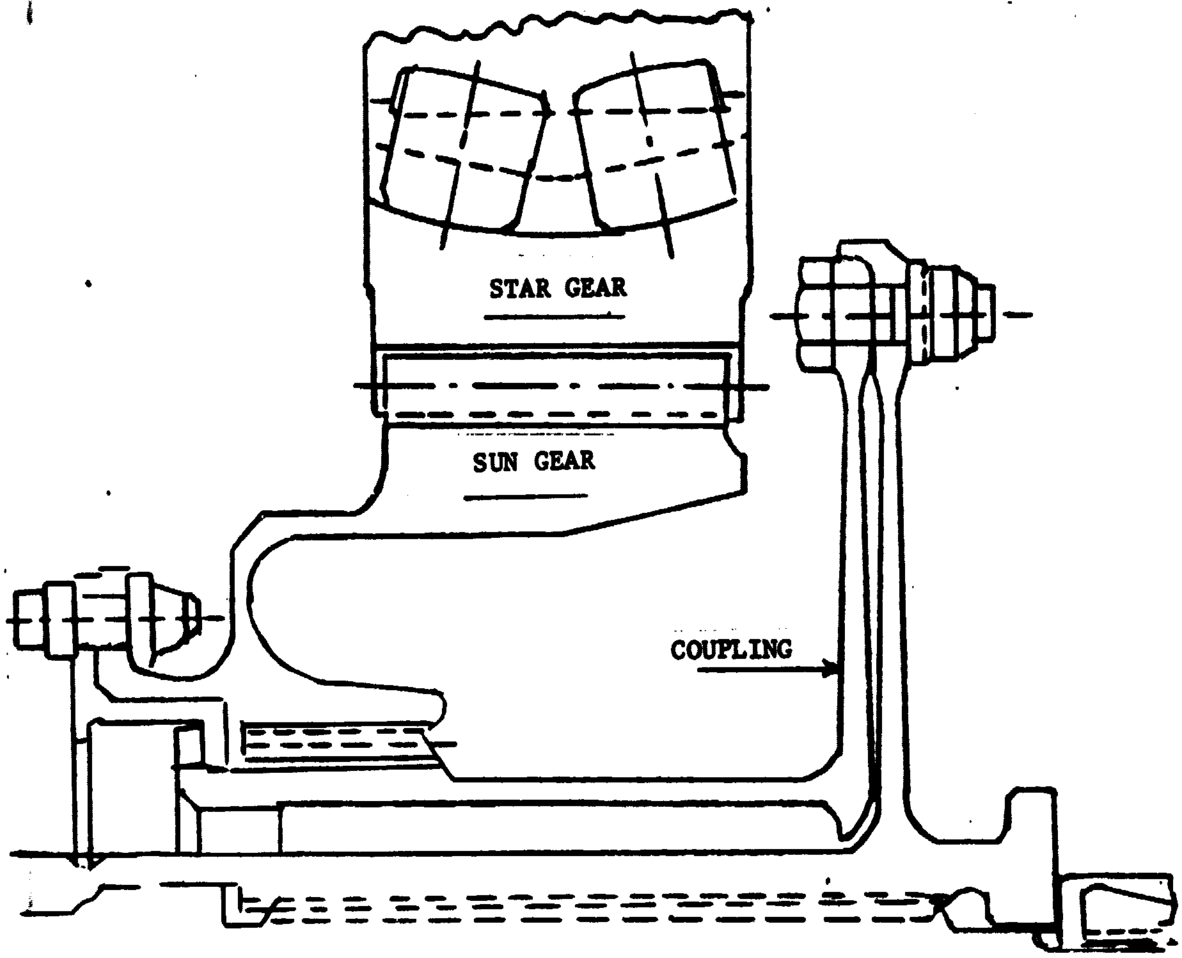

Figure 5.2-22. QCSEE Main Reduction Gear - UTW
Sun Gear Flexible Coupling

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d. During the time the star gear has greatest wobble, accelerometers on the star support show a sharp increase in the response due to subharmonic components of the gear mesh frequency, one-third and one-sixth, but no increase in the gear mesh frequency component.

e. The star gear wobble is a maximum of 14.9 mils double amplitude (D.A.) at 172 Hz which is equal to first order rotation of the star gear at 7560 rpm input shaft speed with 55% torque. Increasing torque to 105% reduces the amplitude and changes the frequency content.

f. The wobble frequency does not match any known natural frequency of the sun gear; but, it is close to the three diameter mode frequency of the ring gear.

g. One possible system that could have a natural frequency with a mode shape that could lead to star gear wobble is the flexible coupling to sun gear configuration.

The time schedule and available funds did not permit further investigation for factors influencing the star gear wobble.

The following recommendations are based on the above UTW reduction gear test vibration data analyses:

a. Perform analyses or tests to confirm or deny that the flexibility of the flex coupling is the prime spring in the system that has a natural frequency which when excited results in increased star gear wobble and possible star gear tooth wear.

b. Review all accelerometer data taken during the reduction gear testing to determine if the relationship between the magnitude of the subharmonic components of the gear mesh and the magnitude of the gear mesh frequency can be used to identify an undesirable gear tooth operation.

c. Review the over-the-wing (OTW) reduction gear design and evaluate the possibility of this phenomenon happening during its endurance testing.

d. During the testing of the over-the-wing reduction gear use proximity pickups to evaluate star gear wobble. Also use accelerometer data to evaluate gear mesh frequency response and subharmonics response as a function of star gear wobble.

e. Review the condition of the gears following operation in the experimental engine to determine if the same influencing factors appear to exist there as in the test rig.

5.2.6 Post Test Inspection

At the conclusion of the reduction gear testing both the test unit and slave unit were completely disassembled and the following inspections performed.

a. Magnetic particle inspection of the following parts:

Sun gears	Star gear supports
Ring gears	Sun gear couplings
Spray tubes	

b. Fluorescent penetrant inspection of the following:

Oil manifold (aluminum)

c. Visual inspection:

All of the above parts
Star gears and bearings

d. Measurements:

Star gear, sun gear and ring gear involute checks.

The star gears could not be magnetic particle inspected without disassembly of the bearings. Due to a very tight delivery schedule, the bearings were not disassembled completely prior to delivery. The rollers in each bearing were visually inspected for indications of skidding at the inner end of the roller cylindrical surface. One roller was removed from each row of rollers in each bearing for inspection of the inner race for indications of distress. A slight discoloration band on the inner race was found in one star gear bearing, location 2 in Figure 5.2-6, by the visual inspection. Although a severe skidding type distress was not evident, replacement of the bearing for the engine installation was recommended. The magnetic particle and fluorescent penetrant inspections did not reveal any distress.

Measurable wear was found on the flanks near the ends of the star gear teeth although wear was negligible at the center of the teeth, apparent evidence of the star gear wobble. The wear was relatively uniform at three points around the circumference of the gear where the measurements were taken.

Spectrographic analysis performed on samples of oil taken from the test rig lubrication system at different times during the test operation was of limited value. Iron content, initially 2 parts per million (ppm) in new oil, did increase from 4 ppm to 7 ppm during DEI QCSEE-13 test operation. The content of other elements in the oil either remained constant or fluctuated upward and downward two or three points for the samples analyzed.

The condition of the reduction gear units was judged acceptable for the initial scheduled operation in the experimental engine. Monitoring of the reduction gear operation and inspections as frequently as possible consistent with the engine test program schedule were recommended.

The UTW reduction gears were delivered to the General Electric Company, Aircraft Engine Group, at Evendale, Ohio, for subsequent installation and test in the QCSEE UTW aircraft turbofan development engine.

5.3 OTW Reduction Gear

5.3.1 Test Program

The scheduled OTW reduction gear unit test program was revised prior to the start of the test operation to expedite the time schedule and conserve expenditures. The units were assembled in the test rig and a gear tooth contact pattern check was conducted. Based on the contact pattern and the UTW unit dynamic operation experience, the involute profiles of the OTW unit star gear teeth were modified to increase tip and flank relief. A second contact pattern check confirmed the desired contact patterns for both the sun/star and the star/ring gear meshes.

The test rig for the OTW reduction gear unit test operation was assembled the same as for the last UTW reduction gear test. There was no scavenge screen in either the test unit or slave unit end of the test rig and the same scavenge outlet baffles or scoops were used. Proximity pickups were installed to sense star gear wobble. These are shown by Figure 5.3-1.

The revised test operation schedule, DEI QCSEE-15, is shown in Table 5-7. The oil specified by General Electric Company for this test operation was Aeroshell Turbine Oil 555 rather than MIL-L-23699 used during the UTW unit tests. This oil was selected because of an apparent higher Ryder gear test load rating than the MIL-L-23699 and potential use in the experimental engine operation. The reduction gear inlet oil temperature specified was 344°K (160°F) the same as for the final UTW unit test operation.

The test schedule was interrupted when attempting the 6400 rpm test point because of high input power requirement (dynamometer overload circuit breaker opened). Test operation at 5800 rpm input speed, 6090 kW (8164 hp) (66.3% torque) was conducted with oil flows of approximately 113, 102, 91 and 80 kg/min (248, 224, 200 and 176 lb/min) at 344°K (160°F) inlet oil temperature.

A review of the reduced oil flow test data and the calculated oil flow requirements with 344°K (160°F) inlet oil temperature indicated that an oil flow of 91 kg/min (200 lb/min) appeared to be adequate although with limited margin. Test operation was resumed with DEI QCSEE-15A operation scheduled in accordance with Table 5-8.

Oil used for this test operation was MIL-L-23699 (Royal Lubricants), the Aeroshell Turbine Oil 555 having been lost by an oil drain line separation during the preceding test operation.

The maximum speed attained with the reduced oil flows was approximately 6600 rpm with 78.9% torque. Operation was also conducted with 108.6% torque at 6000, 6200 and 6400 rpm speeds, 10,324 kW (12,715 hp), 10,648 kW (14,273 hp) and 11,012 kW (14,760 hp) respectively. Higher than anticipated heat rejection continued to be observed. Disassembly and visual inspection of the test unit gears and bearings and the slave unit sun gear indicated all parts in satisfactory condition.

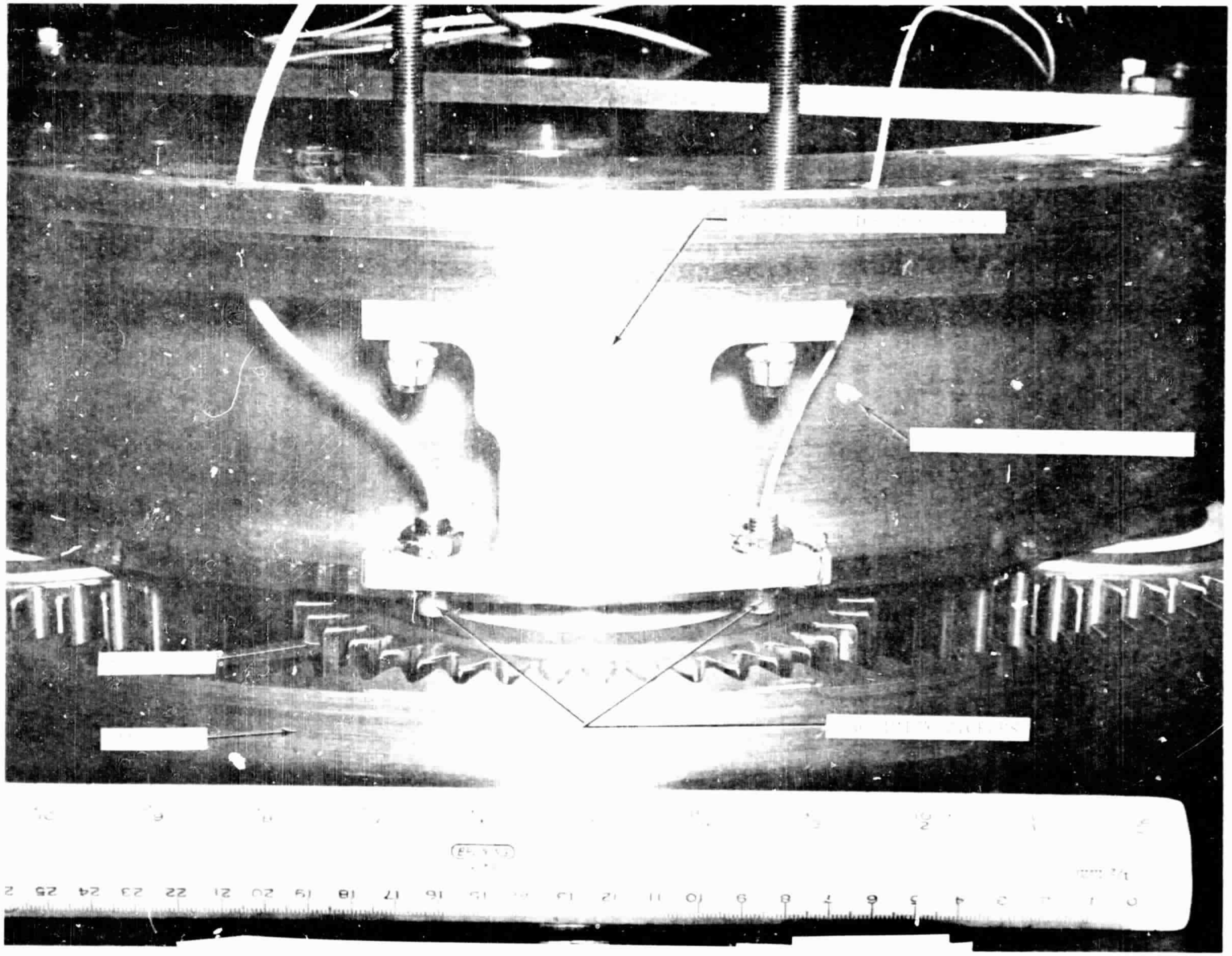


Figure 5.3-1. QCSEE Main Reduction Gear - OTW Unit Star Gear Proximity Pickup

[redacted]

TABLE 5-7. QCSEE MAIN REDUCTION GEAR - OTW UNIT

SCHEDULED DEI QCSEE-15 TEST OPERATION

Oil Type . . . . Aeroshell Turbine Oil 555
Inlet Oil Density. . . . . .967 kg/l (8.05 lb/gal.)
Inlet Oil Temperature. . . . . 344°K (160°F)

Condition	Input Speed	Power		Torque	Oil Flow Rate		Time Minutes		
	RPM	kW	Hp	%	kg/min	lb/min	1st	2nd	3rd
Idle	1181	75	100	4.0	113	250	15	-	
					65	143	10	-	
Exper.	3031	748	1003	15.6	113	250	15		
Idle					84	186	10	120	
Gear Inspection							X		
Approach	6400	6271	9009	66.3	113	250	15		
					102	225	10	120	300
Gear Inspection							X		
Take-off Std. Day	7709	12180	16327	99.7	109	241	-	60	150
Take-Off Hot Day	7934	12531	16798	99.6	113	250	15	60	150
Gear Inspection							X	X	X
Reverse	7366	12682	17000	108.6	113	250	15	60	120
Gear Inspection							X	X	X
Fan Map	8211	14651	19640	112.6	113	250	15	60	120
Gear Inspection							X	X	X
Disassembly							X		

TABLE 5-8. QCSEE MAIN REDUCTION GEAR - OTW UNIT

SCHEDULED DEI QCSEE-15A TEST OPERATION

Oil Type . . . . Aeroshell Turbine Oil 555
Inlet Oil Density. . . . . .967 kg/l (8.05 lb/gal.)
Inlet Oil Temperature. . . . . 344°K (160°F)

Condition	Input Speed	Power		Torque	Oil Flow Rate		Time Minutes
	RPM	kW	Hp	%	kg/min	lb/min	
Exp. Idle	3031	748	1003	15.6	84	186	10
Approach	6400	6271	9009	66.3	91	201	15
Take-Off	7934	12531	16798	99.6	91	201	15
Gear Inspection							X
Reverse	7366	12682	17000	108.6	91	201	15
Gear Inspection							X
Fan Map	8211	14651	19640	112.6	91	201	15
Gear Inspection							X

For the next test operation, DEI QCSEE-16, the following changes were made:

a. The test unit oil manifold was modified to improve oil scavenging or drainage at five accessible star gear bearing locations, Figure 5.3-2.

b. A baffle around the sun gear coupling to deflect coupling windage away from the exiting star gear bearing oil was fabricated and installed.

c. The General Electric Company engine configuration baffle screen around the test unit was installed.

The scheduled test operation for DEI QCSEE-16 is shown by Table 5-9. The maximum operating condition attained, limited by excessive driving power requirement and dynamometer circuit breaker opening, was slightly above 6400 rpm. The highest powers attained were 11,057 kW (14,822 hp) at 112.4% torque and 6200 rpm and 11,009 kW (14,757 hp) at 108.6% torque and 6400 rpm.

The test program was now directed toward identifying the influence of the oil distribution within the gear set on the oil churning power loss. The following modifications were incorporated in the test unit section of the rig.

TABLE 5-9. QCSEE MAIN REDUCTION GEAR - OTW UNIT

SCHEDULED DEI QCSEE-16 TEST OPERATION

Oil Type MIL-L-23699
Inlet Oil Density. . . . . .967 kg/l (8.05 lb/gal.)
Inlet Oil Temperature. . . . . 344°K (160°F)

Condition	Input Speed RPM	Power		Torque	Oil Flow Rate		Time Minutes
		kW	Hp	%	kg/min	lb/min	
Exper.	3031	748	1003	15.6	84	186	10
Idle	3031	3183	4267	66.3	91	201	15
-	4000	4200	5630	66.3	91	201	15
-	5200	5461	7320	66.3	91	201	15
Approach	6400	6721	9009	66.3	91	201	15
-	7934	8333	11171	66.3	91	201	15
Take-Off	7934	12531	16798	99.6	91	201	15
Gear Inspection							
Reverse	7366	12682	17000	108.6	91	201	15
Gear Inspection							
Exp. Idle	3031	748	1003	15.6	68	149	120
Approach	6400	6271	9009	66.3	82	180	120
Gear Inspection							
-	6400	10113	13556	99.6	88	193	120
Gear Inspection							
-	6400	11009	14757	108.5	91	201	60
Gear Inspection							
-	6400	11414	15301	112.6	91	201	60
Gear Inspection							

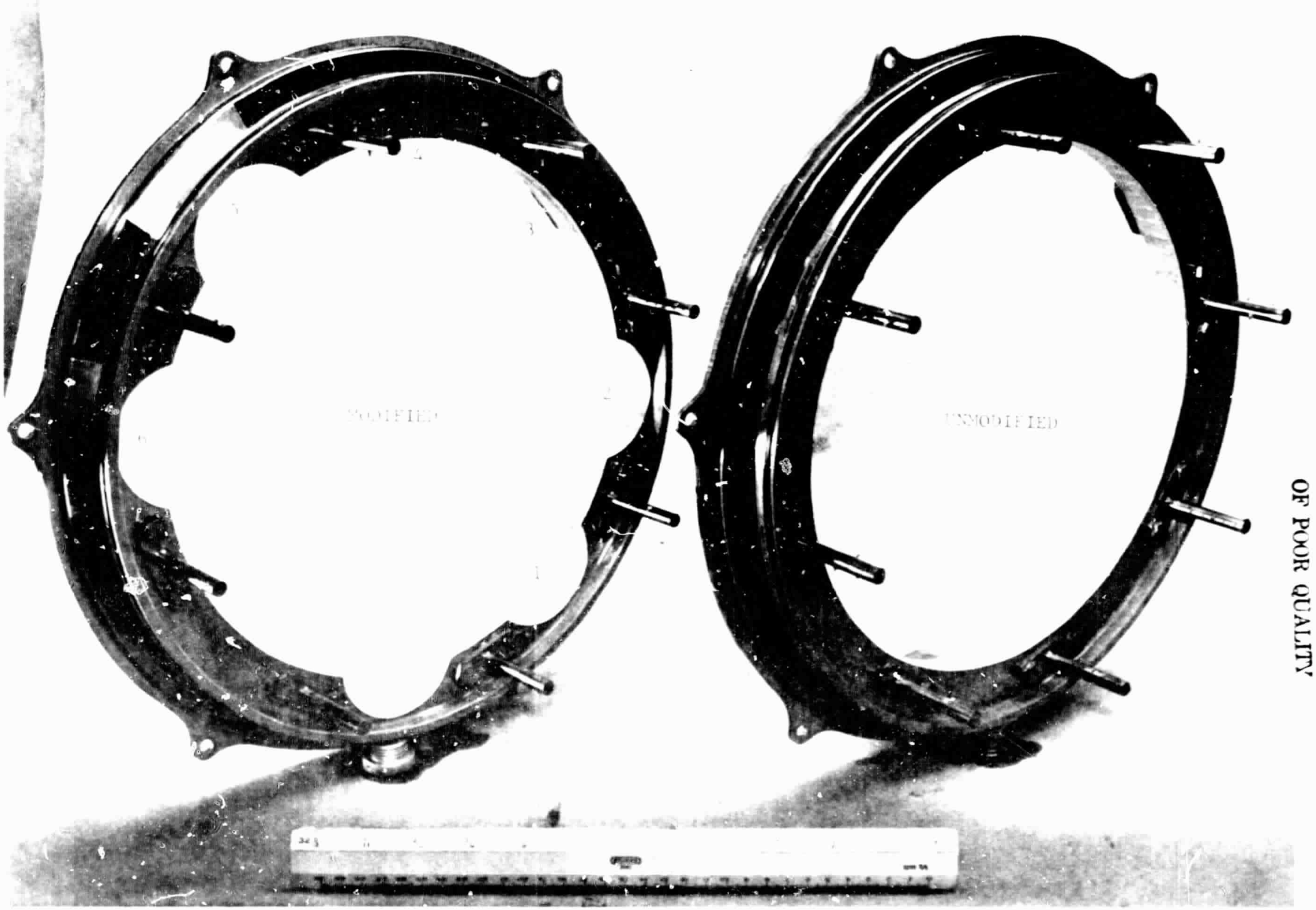


Figure 5.3-2. QCSEE Main Reduction Gear - OTW Unit Oil Manifold Modification

77-254

a. Spray tube oil flow was reduced by plugging three of the five jets on the out of mesh (star gear) side and one jet on the into mesh (sun gear) side, Figure 5.3-3.

b. Added auxiliary oil flow tubes for introducing additional oil into either the inside of the rotating output shaft shroud or to the outside of the rotating output shaft to simulate engine return oil, Figure 5.3-4.

The original oil flow distribution was approximately 64% to the gears and 56% to the star gear bearings with the gear oil being distributed 50% to the sun gear and 50% to the star gear at each mesh. The spray tube revision changed the distribution to approximately 52% to the gears and 48% to the star gear bearings with the gear oil being distributed 67% to the sun gear and 33% to the star gear at each mesh.

Scheduled DEI QCSEE-17 test operating conditions are shown by Table 5-10. The total oil flow was reduced to 68 kg/min (150 lb/min) in the test unit and the maximum torque above 6400 rpm was limited to 50% as a safety precaution. Total oil flow to the slave unit was 91 kg/min (201 lb/min) or 25 GPM.

The maximum operating condition attained, again limited by excessive driving power requirement and dynamometer circuit breaker opening, was 6980 rpm, 5538 kW (7424 hp) (50% torque). Tests were then conducted at 6400 rpm with the auxiliary flows to simulate engine return oil flows.

Both OTW and UTW unit test data were analyzed to identify parameters which could be varied to achieve the maximum test operating speed for a final test operation. As a result of this analysis the following changes were made for DEI QCSEE-18 test operation.

a. The dynamometer input power circuit breakers were set to permit limited time operation at the maximum safe operating load for the dynamometer, approximately 680 amperes each at 250 volts; total input of 340 kW (455 hp). Actual voltage and power available at 680 amperes was 240 volts; 326 kW (437 hp).

b. Additional modifications made to the test unit spray tubes, Figure 5.3-3.

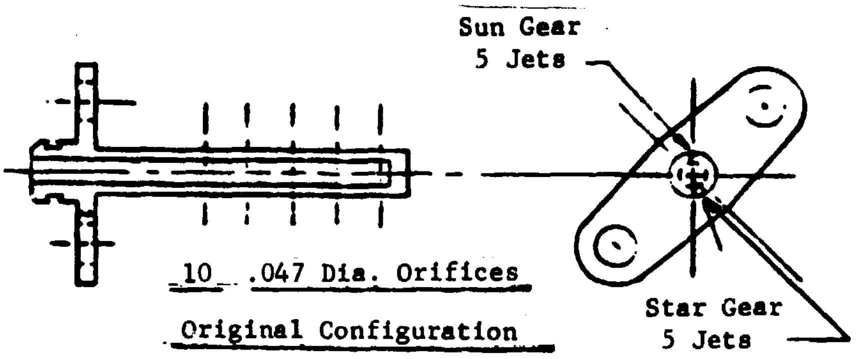
c. Modified slave unit spray tubes similar to the test unit ones.

d. Removed General Electric Company oil scavenge screen from test unit end of rig.

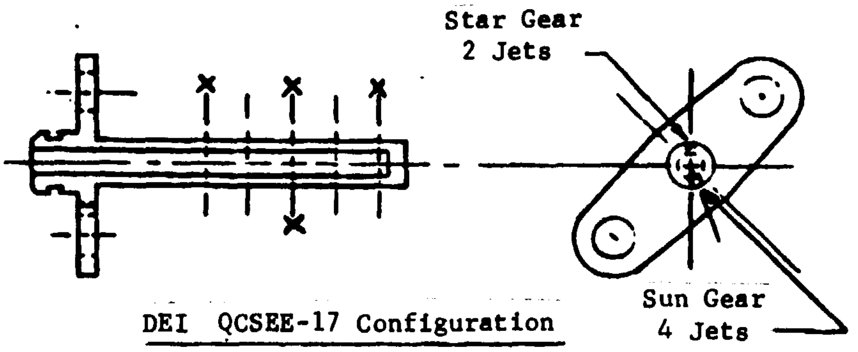
e. Installed oil scavenge pump for the test unit end of the rig.

f. Installed proximity pickup to sense axial movement of the input shaft.

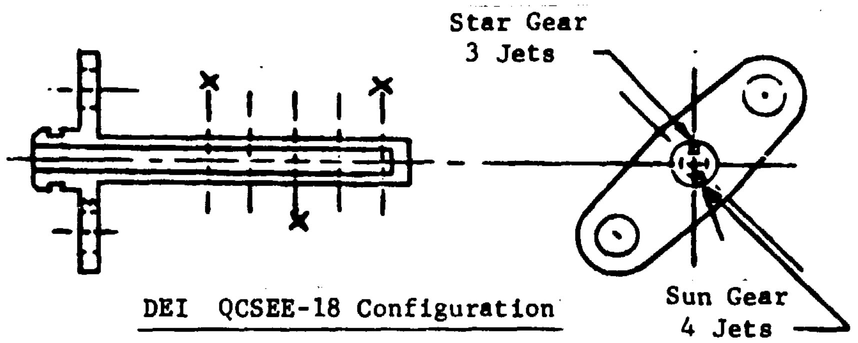
g. Torquemeter calibration for torque versus millivolt readout checked. (Inconsistency between power input indicated by the torquemeter torque and the electrical power input noted during data analysis.)



Original Configuration



DEI QCSEE-17 Configuration



DEI QCSEE-18 Configuration

Orifices "X" Plugged to Reduce Oil Flow

Figure 5.3-3 Spray Tube Modifications
QCSEE MRG OTW Unit

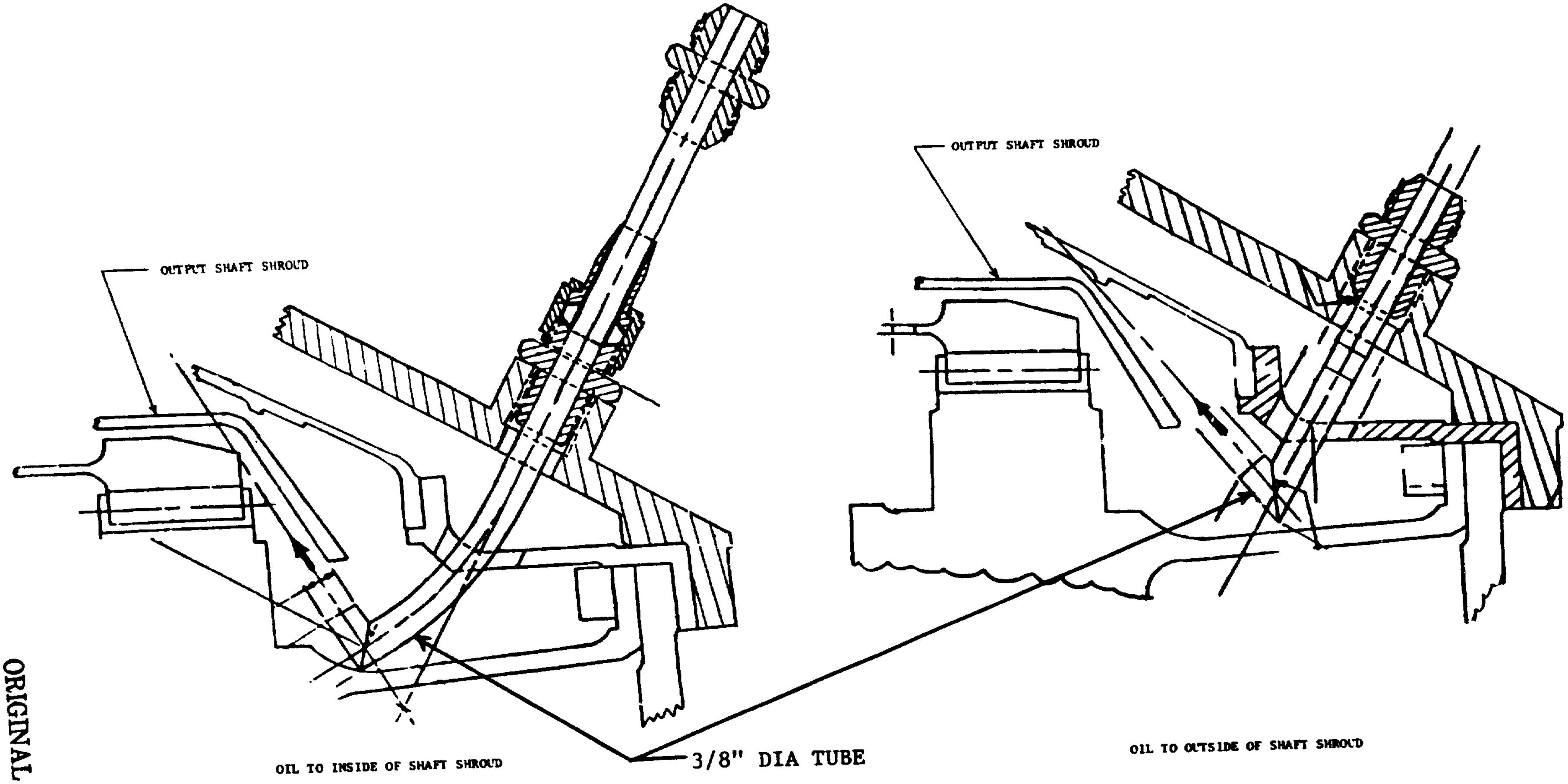


Figure 5.3-4. Auxiliary Oil Flow Tubes to Simulate Engine Return Oil

TABLE 5-10. QCSEE MAIN REDUCTION GEAR - OTW UNIT

SCHEDULED DEI QCSEE-17 TEST OPERATION

Oil Type MIL-L-23699
Inlet Oil Density. . . . . .967 kg/l (8.05 lb/gal.)
Inlet Oil Temperature. 344°K (160°F)

Condition	Input Speed	Power		Torque	Oil Flow Rate			
					Gear Rate		Auxiliary	
	RPM	kW	Hp	%	kg/min	lb/min	kg/min	lb/min
	3031	748	1003	15.6	68	150		
	3031	3183	4267	66.3	68	150		
	4000	4200	5630	66.3	68	150		
	5200	5461	7320	66.3	68	150		
	6400	6721	9009	66.3	68	150		
	6400	5078	6807	50.0	68	150		
	6600	7019	5236	50.0	68	150		
	6800	5395	7232	50.0	68	150		
	7000	5554	7445	50.0	68	150		
Gear Insp								
	7000	5554	7445	50.0	68	150		
	7200	5713	7658	50.0	68	150		
	7400	5871	7870	50.0	68	150		
	7600	6030	8083	50.0	68	150		
	7800	6189	8296	50.0	68	150		
	8000	6347	8508	50.0	68	150		
Gear Insp								
	6400	6721	9009	66.3	68	150	0	0
	6400	6721	9009	66.3	68	150	7	15
	6400	6721	9009	66.3	68	150	13.5	30
	6400	6721	9009	66.3	68	150	18	40
	6400	6721	9009	66.3	68	150	23	50

This latest spray tube revision gave an oil flow distribution of approximately 56% to the gears and 44% to the star gear bearings with the gear oil being distributed 57% to the sun gear and 43% to the star gear at each mesh.

Scheduled DEI QCSEE-18 test operating conditions are shown by Table 5-11. The maximum conditions at which OTW operation was accomplished during this test are as follows:

Condition	Power		Torque	Speed	
	kW	(hp)	%	rpm	(%)
Maximum Power	11342	(15204)	100	7148	(90)
Maximum Speed	5993	(8034)	50	7554	(95)
Maximum Torque	11012	(14762)	108	6400	(80)

Corresponding OTW maximum gear pitch line velocity at 95% speed was 113.3 m/s (22,300 fpm) and the maximum star gear spherical roller bearing DN was 0.85 x 10^6.

The total operating time on the QCSEE MRG OTW units was approximately 36 hours.

TABLE 5-11. QCSEE MAIN REDUCTION GEAR - OTW UNIT

SCHEDULED DEI QCSEE-18 TEST OPERATION

Oil Type MIL-L-23699
Inlet Oil Density. . . . . .967 kg/l (8.05 lb/gal.)
Inlet Oil Temperature. . . . . 344°K (160°F)

Condition	Input Speed RPM	Power kW	Power Hp	Torque %	Oil Flow Rate kg/min	Oil Flow Rate lb/min	Time Minutes
	3031	3183	4267	66.3	68	150	15
	4000	4200	5630	66.3	68	150	15
	5200	5461	7320	66.3	68	150	15
	6400	6721	9009	66.3	68	150	15
	6400	5078	6807	50.0	68	150	15
	7000	5554	7445	50.0	68	150	15
Gear Inspection							
	7000	5554	7445	50.0	68	150	15
	7368	5846	7836	50.0	68	150	15
Gear Inspection							
	7368	5846	7836	50.0	68	150	15
	7709	6116	8199	50.0	68	150	15
Gear Inspection							
	7709	6116	8199	50.0	68	150	15
	7934	6295	8438	50.0	68	150	15
					Oil Pressure PSIG		
	3031	3183	4267	66.3	42		15
	6400	6721	9009	66.3	42		15
	7000	7351	9853	66.3	42		15
	7368	7737	10371	66.3	42		15
	7368	12674	16989	108.6	42		15
Gear Inspection							
	7368	12674	16989	108.6	42		15
	7709	12181	16329	99.6	42		15
	7934	12537	16805	99.6	42		15

5.3.2 Oil Temperature

Oil temperature rise is plotted as a function of input sun gear shaft speed in Figures 5.3-5, 5.3-6, 5.3-7 and 5.3-9 for the various operating conditions where sufficient data points with only one variable were available. Projecting the plotted test data curves to the 100% speed point was found to be the most convenient method for comparing the results of the several modifications in hardware and operating parameters.

Data for DEI QCSEE-15 and 15A operation at 66.3% and 108.6% torque with the oil flow reduced to 91 kg/min (200 lb/min) are presented by Figure 5.3-5. These data are for operation with no baffle screens, the same scavenging configuration used during the final UTW unit test operation. As projected, an oil temperature rise of 55°K (99°F) at 7961 rpm is indicated for 66.3% torque and 56°K (101°F) for 108.6% torque. The closeness and scatter for the few points limits the accuracy of the projection. The 344°K (160°F) inlet oil temperature and the above temperature rise results in an oil out temperature of approximately 400°K (261°F). Extrapolated oil temperature rise at 5800 rpm, 66.3% torque and 114 kg/min (250 lb/min) oil flow was 36°K (55°F). With the oil flow reduced to 80 kg/min (177 lb/min) the oil temperature rise increased to 33°K (60°F).

Data for DEI QCSEE-16 operation at 66.3% and 99.6% torque at speeds to 6400 rpm and approximately 92 kg/min (200 lb/min) oil flow are shown by Figure 5.3-6. Projection of the curves to 7961 rpm, the 100% speed point, indicates an oil temperature rise of 64°K (115°F) at 66.3% torque and 65.5°K (118°F) at 99.6% torque. At the 66.3% torque the projected oil temperature rise is approximately 9°K (16°F) higher than for the previous test operation. Projected oil temperature rise for 100% torque would be 66°K (119°F) and result in an outlet temperature of 410°K (279°F). At the 6400 rpm speed point measured oil temperature rise was 38.9°K (70°F) for the previous test and 41°K (74°F) for this test. The individual effect if any of the three modifications, i.e., oil manifold relief modification, installation of the coupling windage baffle and General Electric Company screen, could not be determined. The difference in the slopes of the DEI QCSEE-15 and the QCSEE-16 could be real or could be the result of the accuracy of projecting the data from the relatively closely spaced data points in Figure 5.3-5. At least, there was no overall improvement attributable to the three modifications.

Data for DEI QCSEE-17 operation at 66.3% and 50% torque with approximately 68 kg/min (150 lb/min) oil flow are shown by Figure 5.3-7. Projection of curves to 7961 rpm, the 100% speed point, indicates an oil temperature rise of 68.5°K (123°F) for the 66.3% torque. Comparison of Figures 5.3-6 and 5.3-7 shows that with reduced oil flow a greater temperature rise results.

The effect of added oil being supplied into the output shaft shroud is shown by Figure 5.3-8. With a total test unit oil flow of approximately 92 kg/min (202 lb/min) the oil temperature rise is 36°K (65°F). Under the same speed, load and oil flow during DEI QCSEE-16 operation the oil temperature rise was 41°K (74°F). These data indicate that introducing part of the oil directly into the star gear/ring gear mesh area does not produce the same effect as the same total flow through the bearings and gear spray tubes at low (88%) speed and (66%) torque.

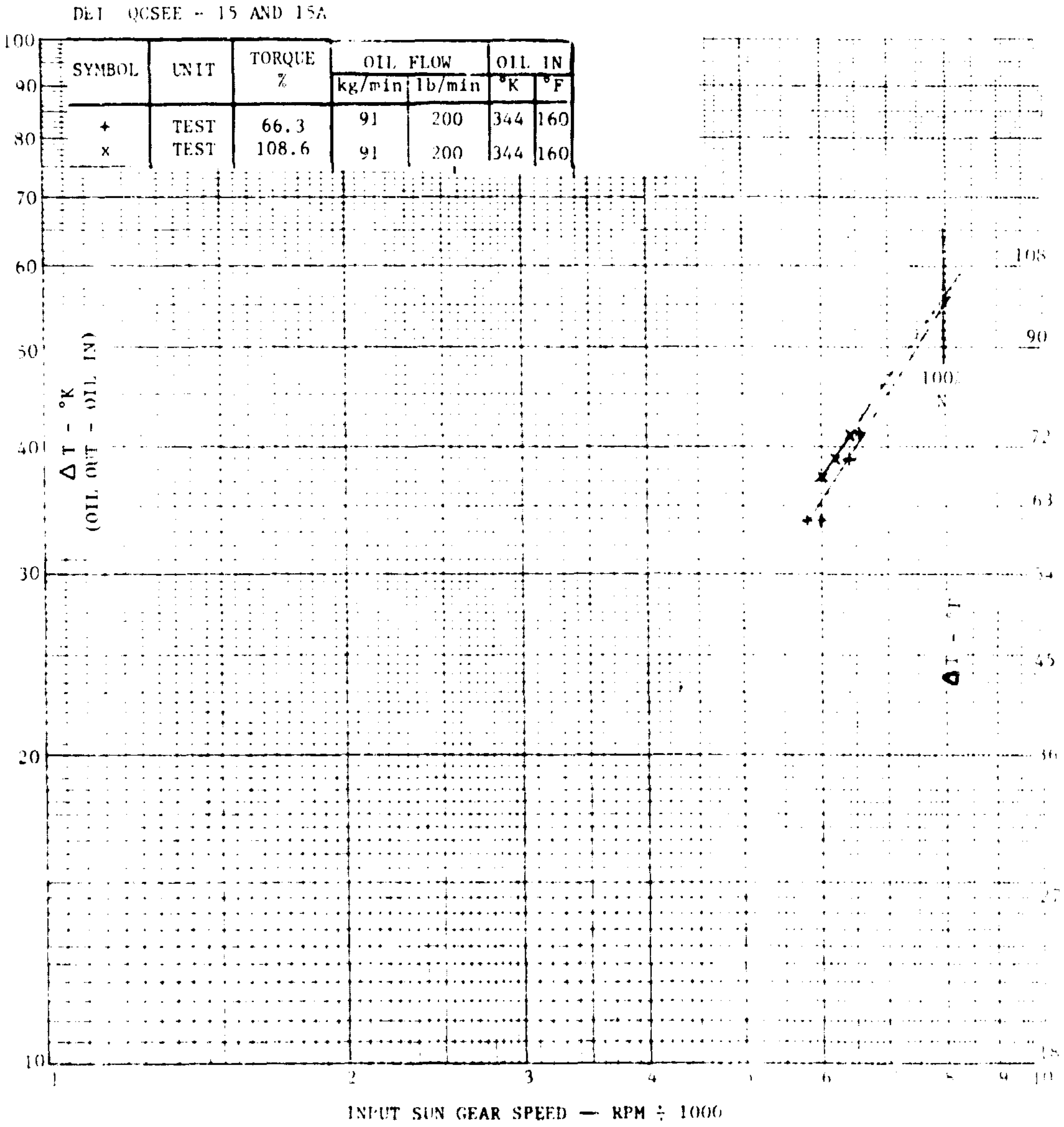
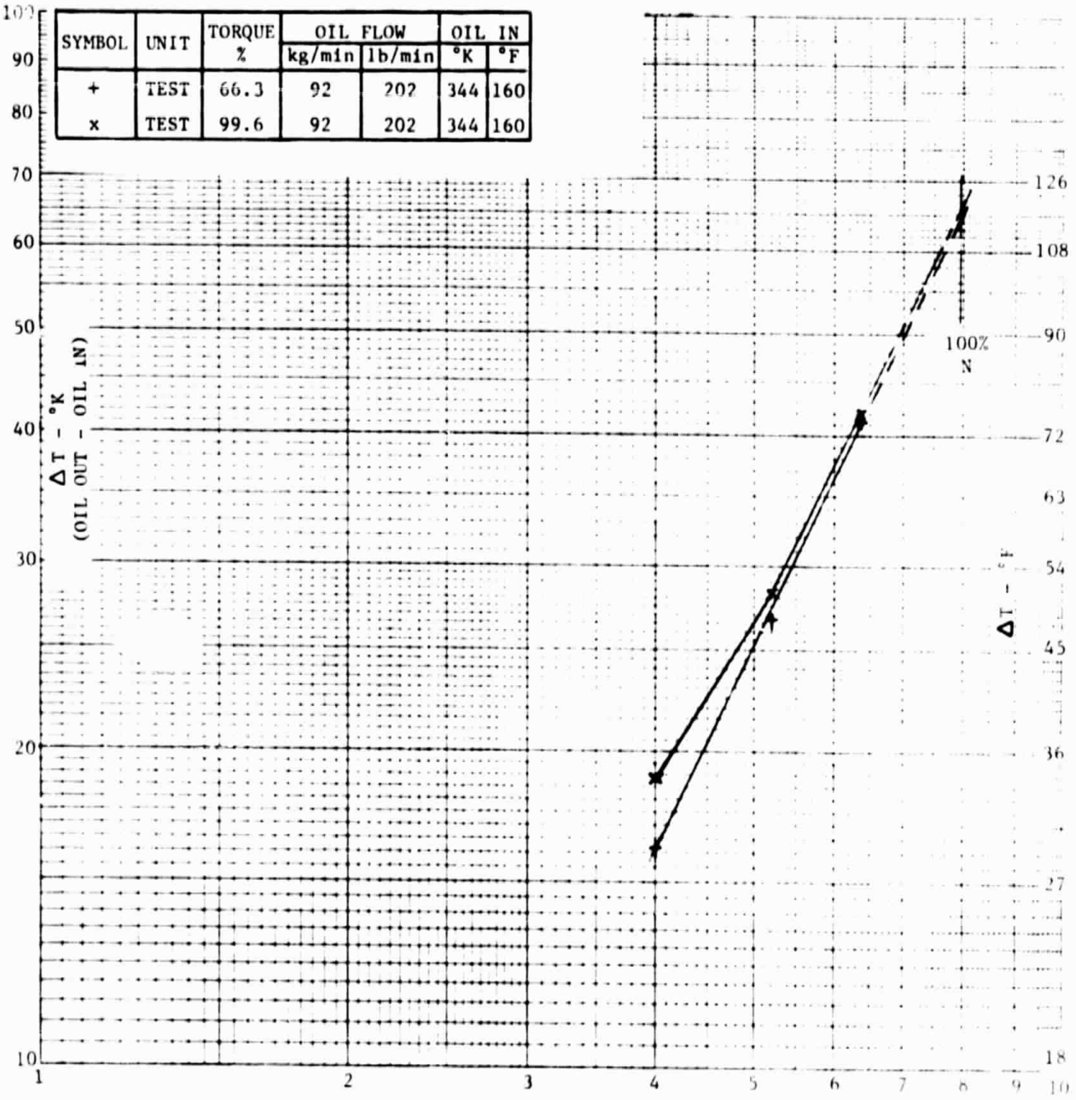


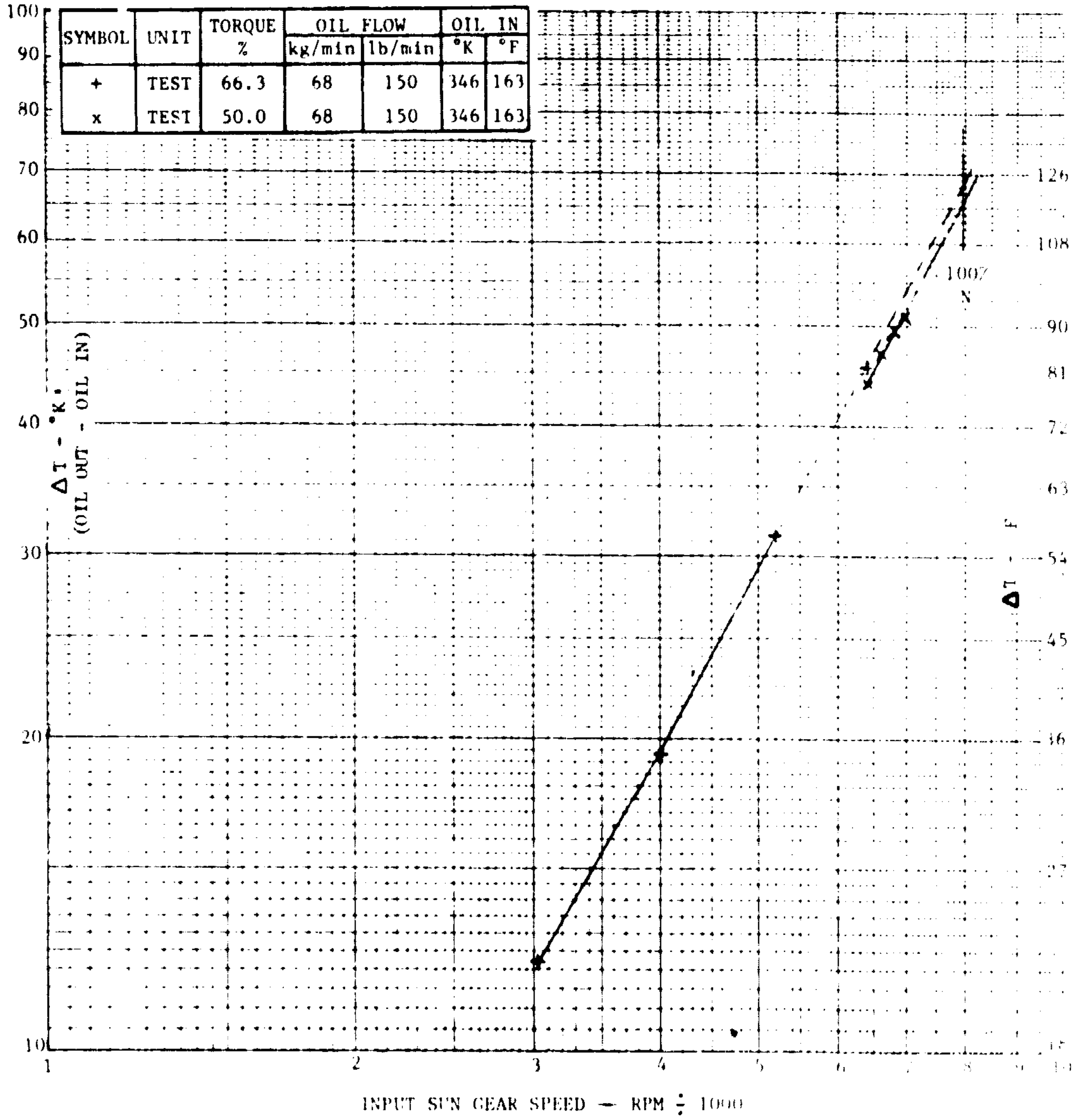
Figure 5.3-5. QCSEE Main Reduction Gear - OTW Test Unit
Oil Temperature Rise Vs Speed

DEI QCSEE-16



SYMBOL	UNIT	TORQUE %	OIL FLOW		OIL IN	
			kg/min	lb/min	°K	°F
+	TEST	66.3	92	202	344	160
x	TEST	99.6	92	202	344	160

Figure 5.3-6. QCSEE Main Reduction Gear - OTW Test Unit
Oil Temperature Rise Vs Speed



SYMBOL	UNIT	TORQUE %	OIL FLOW kg/min	OIL FLOW lb/min	OIL IN °K	OIL IN °F
+	TEST	66.3	68	150	346	163
x	TEST	50.0	68	150	346	163

Figure 5.3-7. QCSEE Main Reduction Gear - OTW Test Unit Oil Temperature Rise Vs Speed

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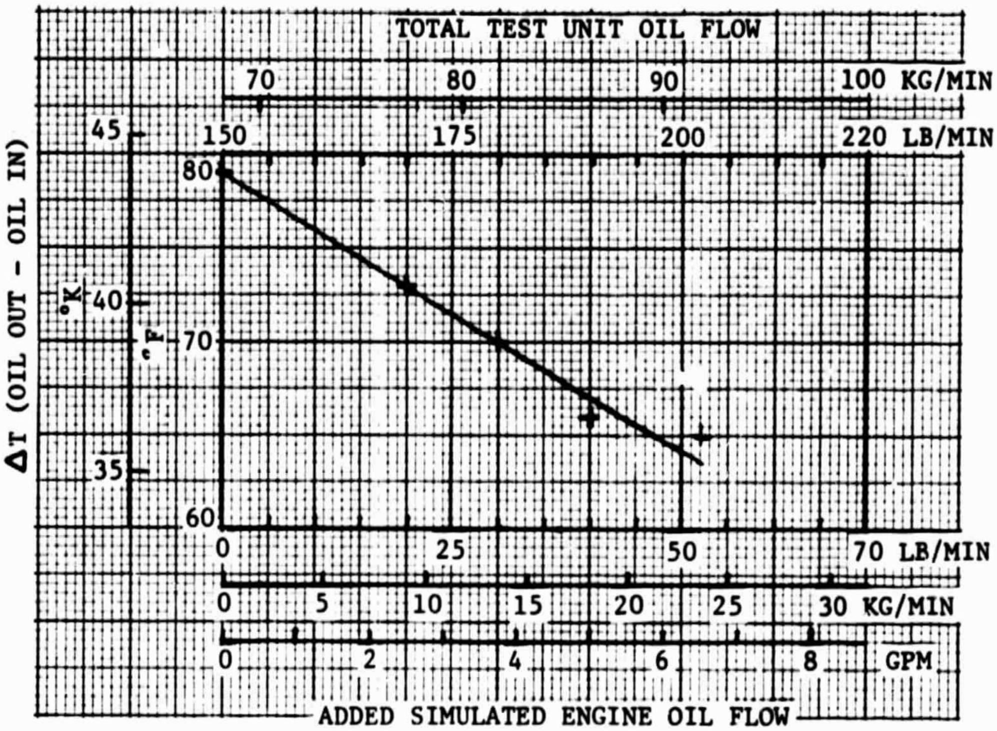


SPEED . . . . 6400 RPM (80% N)
POWER . . . . 6720 kW (9008 HP)
INLET OIL TEMPERATURE . . 344°K (160°F)

Figure 5.3-8. QCSEE Main Reduction Gear - OTW Test Unit Simulated Engine Return Oil Flow Effect on Oil ΔT (DEI QCSEE-17)

Data for DEI QCSEE-18 operation is shown by both Table 5-12 and Figure 5.3-9. A projection of the 66.3% torque, 91 kg/min (202 lb/min) oil flow curve to 7961 rpm indicates an oil temperature rise of 59°K (106°F). With an inlet oil temperature of 344°K (160°F) the oil out temperature becomes 403°K (266°F). Using the 68 kg/min (150 lb/min) oil flow the projected curve indicates 68°K (122°F) oil temperature rise for an oil out temperature of 412°K (282°F), or about 9°K (16°F) above the value with the higher flow at 100% design speed and 66.3% torque. At 100% torque, the oil temperature rise would increase about 12°K (21°F).

Assuming the same slope as indicated for the lower torques in Figure 5.3-9, the curve for 100% torque, 68 kg/min (150 lb/min) oil flow and 339°K (150°F) inlet oil temperature projected from a temperature rise of 61°K (109°F) at 7148 rpm indicates a temperature rise of approximately 73°K (132°F) at the

TABLE 5-12. QCSEE MAIN REDUCTION GEAR - OTW UNIT

DEI QCSEE-18 TEST OPERATION

Inlet Oil Temperature . . . . 344-346°K (160-163°F)

Input Speed	Power		Torque	Oil Flow Rate		Oil Temp Rise	
RPM	kW	Hp	%	kg/min	lb/min	°K	°F
3000	3150	4223	66.3	68	150	12	22
4000	4200	5630	66.3	68	150	20	36
5200	5460	7319	66.3	68	150	32	58
6400	6720	9008	66.3	68	150	46	83
6400	5078	6807	50	68	150	45	81
6800	5470	7332	50	68	150	49	89
7000	5554	7445	50	68	150	53	95
7366	5844	7834	50	68	150	58	104
7554	5993	8034	50	68	150	61	109
3031	3182	4266	66.3	92	203	11	19
6400	6720	9008	66.3	92	202	41	73
6800	7141	9572	66.3	92	202	46	82
7000	7350	9853	66.3	92	202	48	86

Inlet Oil Temperature . . . . 339°K (150-151°F)

Input Speed	Power		Torque	Oil Flow Rate		Oil Temp Rise	
RPM	kW	Hp	%	kg/min	lb/min	°K	°F
7000	8330	11167	75	68	150	56	100
7000	9450	12668	85	68	150	56	101
7000	9950	13338	90	68	150	57	102
7000	10884	14590	100	68	150	58	104
7148	11342	15204	100	68	150	61	109
7359	5840	7827	50	68	150	59	107
7365	8766	11750	75	68	150	61	109

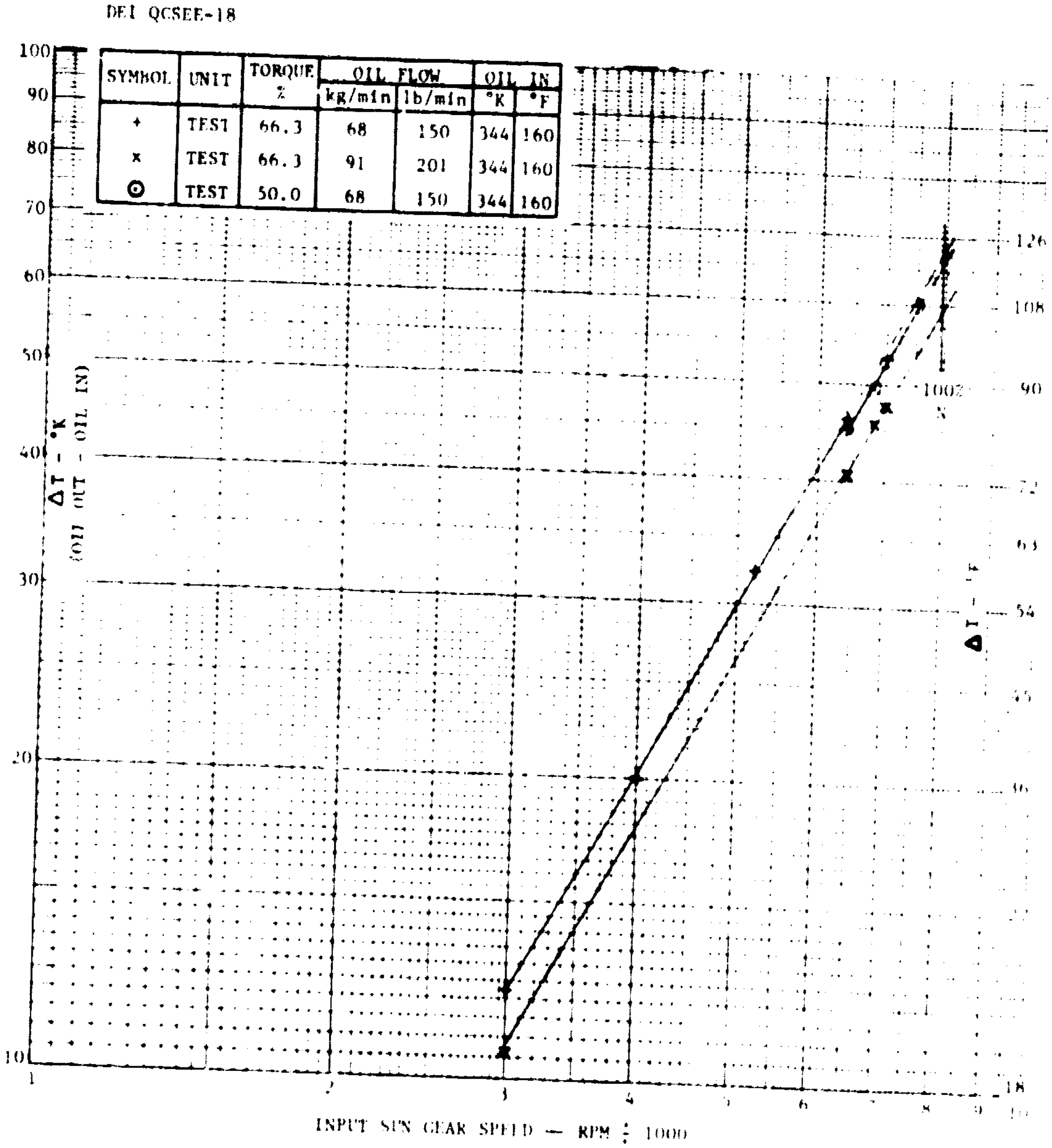


Figure 5.3-9. QCSEE Main Reduction Gear - OTW Test Unit
Oil Temperature Rise Vs Speed

100% torque point. This also results in an oil out temperature of 412°K (282°F). Maintaining the same inlet oil temperature and increasing the oil flow will result in an oil out temperature reduction of about 12°K (21°F).

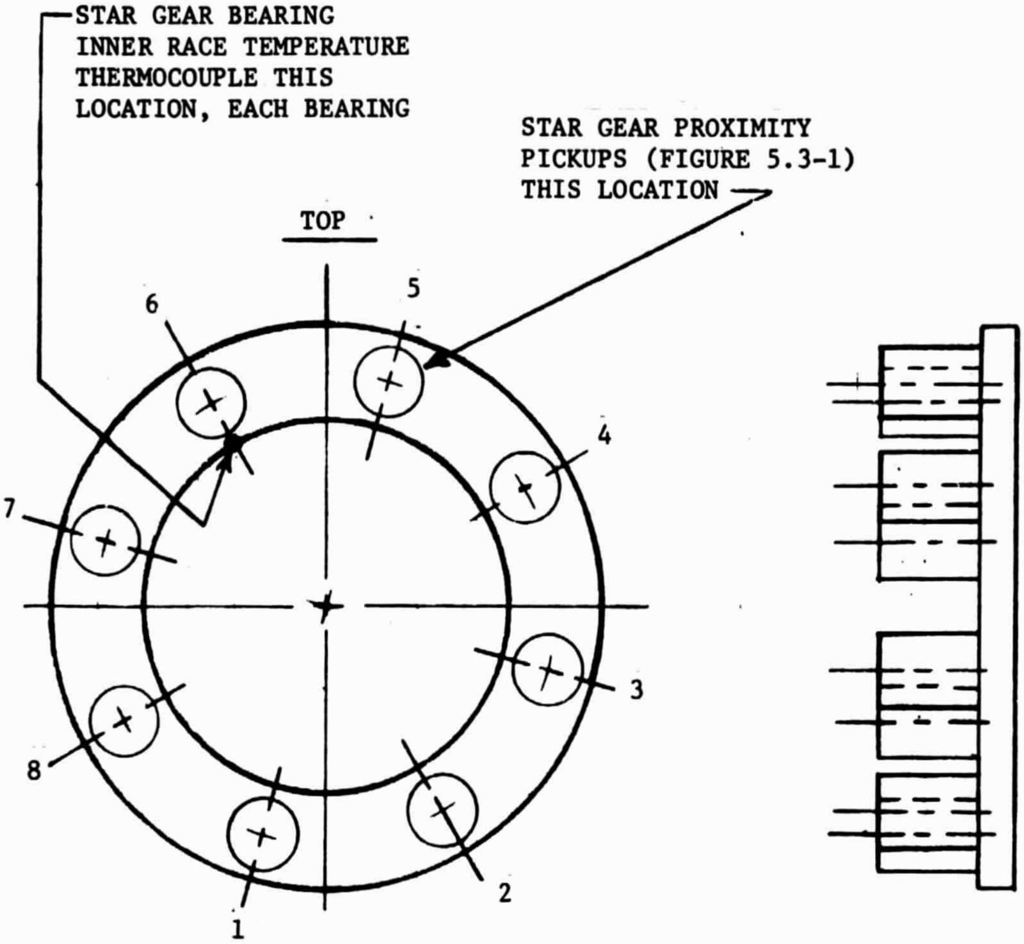
5.3.3 Bearing Temperature

Differentials between oil inlet temperature and temperatures at the faces of the star gear spherical roller bearing inner races are presented for operating parameter variables of speed, load, inlet oil temperature and bearing location. Figure 5.3-10 identifies the bearing locations indicated on the following charts. The star gear face proximity pickups discussed in section 5.3.5 were at bearing location number 5. The oil temperature rise through the reduction gear is also shown on the bearing temperature charts.

A comparison of bearing to inlet oil temperature differentials for DEI QCSEE-15 and QCSEE-16 test operations is shown by Figure 5.3-11. The combination of the oil manifold cutouts, sun gear coupling shroud and installation of General Electric Company screen resulted in a small increase in the bearing temperatures at the 6400 rpm input shaft speed. During QCSEE-15 operation the thermocouple at bearing location number 6 was inoperative. One of the two oil passages in bearing location number 8 trunnion was subsequently found to have been restricted during this operation and the cause for that bearing temperature reading high. The temperature of the bearing at location number 5 is the highest in this as well as all other operations at input speeds above 4000 rpm. The high temperatures at this location has been attributed to restriction of the oil flow from the bearing by the proximity pickup support. Although data at speeds below 6400 rpm have not been plotted, it was observed that at speeds below 5200 rpm the average bearing temperatures were higher than the outlet oil temperatures, at 5200 rpm they were approximately equal and above 5200 rpm the average bearing temperatures were lower than the outlet oil temperatures. The cutouts made in the oil manifold for QCSEE-16 operation were at bearing locations numbers 1, 2, 5, 6 and 8. No influence of the cutouts in comparison to the locations not relieved is apparent. The oil inlet to the oil manifold is at bearing location number 4.

Bearing and oil temperature differentials relative to the inlet oil temperatures for 6400 rpm to 7000 rpm speeds with the reduction gear oil flow reduced to 68 kg/min (150 lb/min) during DEI QCSEE-17 test operation are shown by Figure 5.3-12. The estimated oil flow to each bearing for this operation is 4.1 kg/min (9 lb/min), the same as for Figure 5.3-11 operation data.

Bearing and oil temperature differentials relative to inlet oil temperatures for 7000, 7366 and 7554 rpm input speeds during DEI QCSEE-18 test operation are shown by Figure 5.3-13. Although the total oil flow to the reduction gear is the same as during the preceding test, Figure 5.3-12, the estimated individual bearing flows are 3.75 kg/min (8.25 lb/min) as a result of spray tube modifications to supply additional oil to the gears. The temperatures for the 7000 rpm data in Figure 5.3-13 average approximately 1°K to 2°K higher than shown in Figure 5.3-12 which is attributable to the reduced oil flow rate to the bearing.

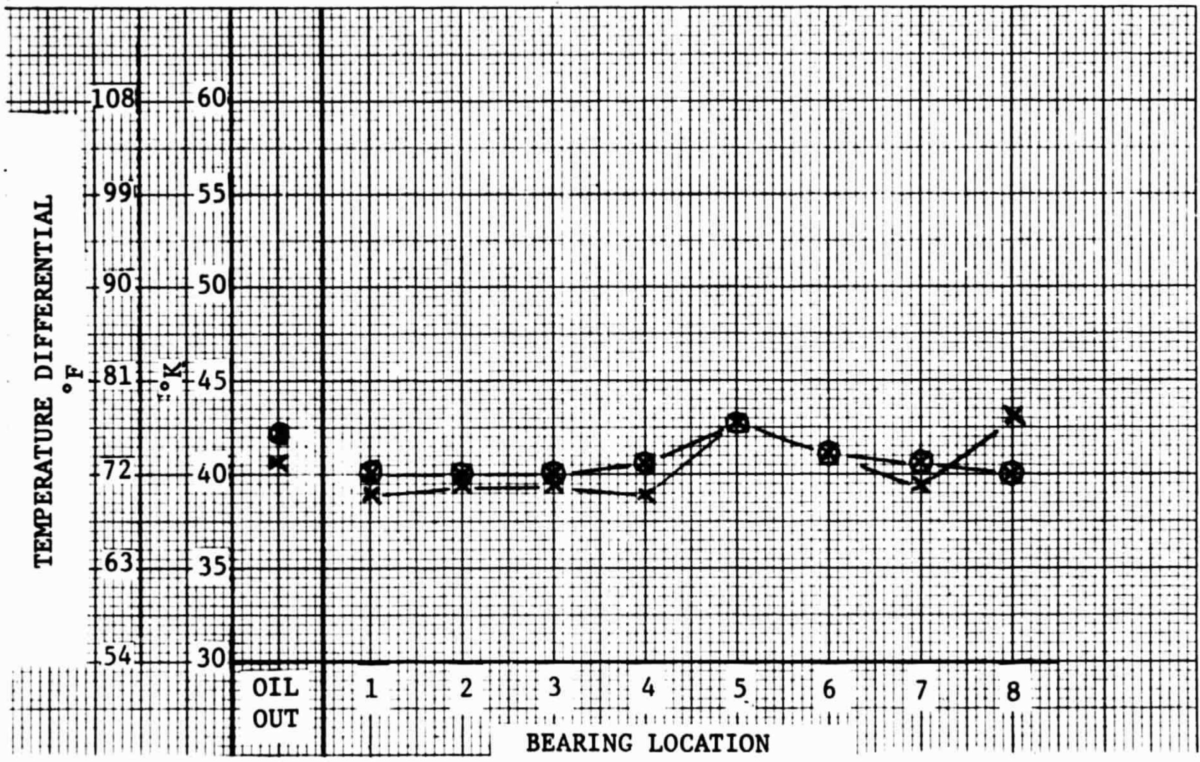


STAR GEAR BEARING INNER RACE TEMPERATURE THERMOCOUPLE THIS LOCATION, EACH BEARING

STAR GEAR PROXIMITY PICKUPS (FIGURE 5.3-1) THIS LOCATION

BEARING LOCATIONS

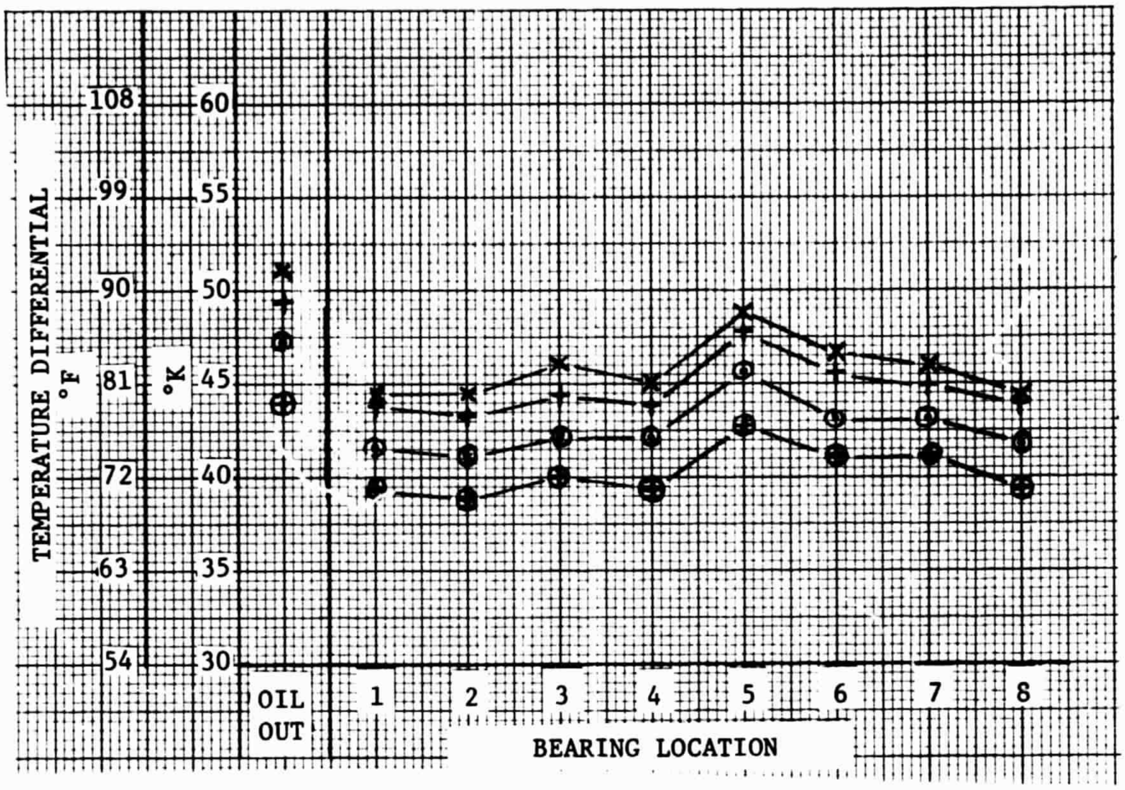
Figure 5.3-10. QCSEE Main Reduction Gear
OTW Unit



SPEED . . . . 6400 RPM (80%)
TORQUE. 108.6%
POWER . . . . 11010 kW (14760 HP)
OIL FLOW. . . . . 91 Kg/MIN (200 LB/MIN)
OIL IN TEMP . . . . 346°K (162°F)
SYMBOL:
x . . . . DEI QCSEE-15 OPERATION
⊗ . . . . DEI QCSEE-16 OPERATION

Bearing and Oil Out to Oil In
Temperature Differentials

Figure 5.3-11. QCSEE Main Reduction Gear - OTW Test Unit



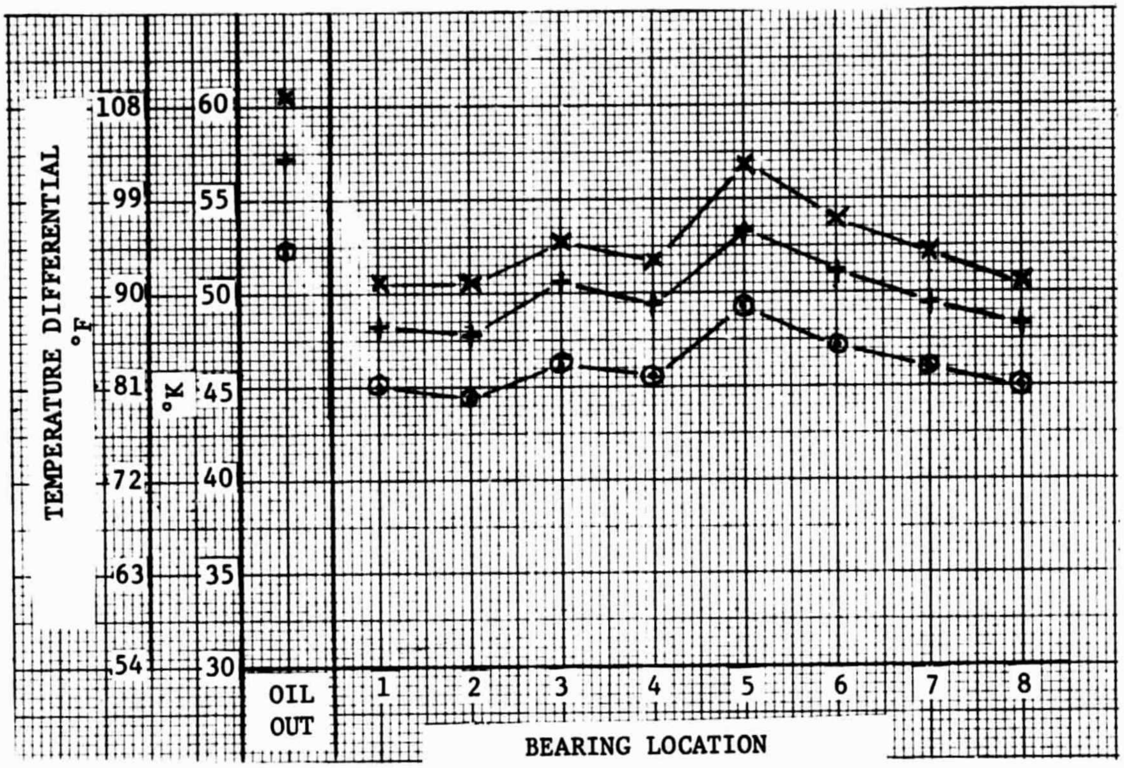
TORQUE 50%
OIL FLOW. . . . . 68 Kg/MIN (150 LB/MIN)
OIL IN TEMP . . . . 346°K (164°F)

SYMBOL	SPEED	POWER
x	7000 RPM (88%)	5540 kW (7445 HP)
+	6800 RPM (85.5%)	5395 kW (7232 HP)
⊙	6600 RPM (83%)	5236 kW (7019 HP)
⊕	6400 RPM (80%)	5077 kW (6806 HP)

REFERENCE . . . . DEI QCSEE-17 OPERATION

Bearing and Oil Out to Oil In
Temperature Differentials - Variable Speed

Figure 5.3-12. QCSEE Main Reduction Gear - OTW Test Unit



TORQUE 50%
OIL FLOW. . . . . 68 Kg/MIN (150 LB/MIN)
OIL IN TEMP . . . . 344°K (160°F)

SYMBOL	SPEED	POWER
x	7554 RPM (95%)	5993 kW (8034 HP)
+	7366 RPM (92.5%)	5844 kW (7834 HP)
⊙	7000 RPM (88%)	5554 kW (7445 HP)

REFERENCE . . . . DEI QCSEE-18 OPERATION

Bearing and Oil Out to Oil In
Temperature Differentials - Variable Speed

Figure 5.3-13. QCSEE Main Reduction Gear - OTW Test Unit

Data for operation at 75%, 90% and 100% torque at 7000 rpm (88%) with the inlet oil temperature reduced to 339°K (151°F) is shown by Figure 5.3-14. Preceding data presented in Figure 5.3-13 were for 344°K (160°F) inlet oil temperature and 50% torque.

A comparison of bearing and oil temperature differentials relative to the inlet oil temperature for inlet oil temperatures of 340°K (152°F) and 345°K (162°F) are presented by Figure 5.3-15. This shows that a reduction of approximately 5°K (10°F) in the inlet oil temperature resulted in an increase in the average bearing temperature differential of approximately 2.2°R (4°F).

The bearing to oil inlet temperature differential for bearing location number 6 from Figures 5.3-12 and 5.3-13 are plotted on Figure 5.3-16 and the slope of the curve through the points extended through the 100% speed point of 7961 rpm. This indicates an expected bearing to inlet oil temperature differential of approximately 58.5°K (105°F) or a bearing operating temperature of 403°K (265°F) for operation at 100% speed, 50% torque and 68 kg/min (150 lb/min) oil flow entering the reduction gear at 344°K (160°F). Based on the 100% torque bearing to inlet oil temperature differential shown on Figure 5.3-14 and assuming the same temperature-speed curve slope as for 50% torque, the curve projected to 100% speed, indicates a bearing to inlet oil temperature differential of approximately 66.5°K (120°F) for operation at 100% speed, 100% torque and 68 kg/min (150 lb/min) oil flow entering the reduction gear at 339°K (150°F). This results in an operating bearing temperature of 405°K (270°F).

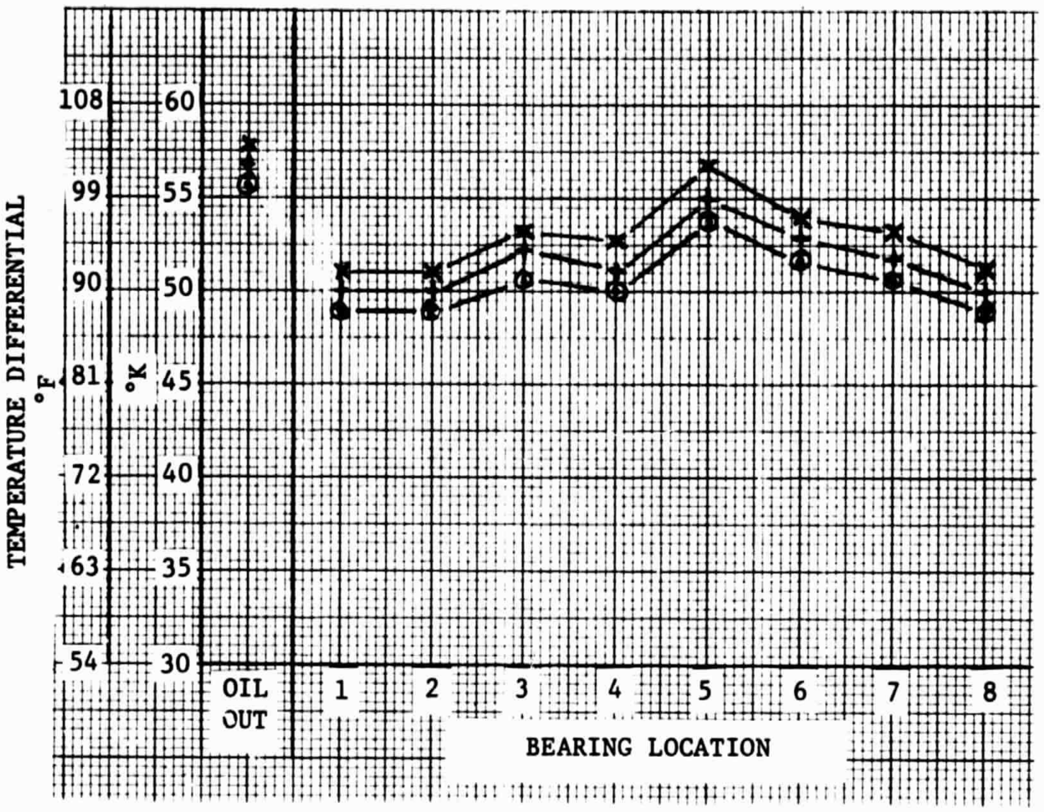
This projected temperature is approximately 7°K (12°F) greater than the maximum bearing temperature experienced during the test operation.

5.3.4 Mechanical Efficiency

The power loss measurement used for calculating the OTW reduction gear efficiency is the heat rejection to the oil based on the oil flow to the reduction gear and the temperature differential between entering and exiting oil.

Heat rejection to the oil and the calculated efficiency for various test points are presented in Tables 5-13 through 5-17. Heat rejection rates versus speed for several test operating conditions are presented by Figures 5.3-17 through 5.3-19. The heat rejection data are plotted on the basis of available sets of test points having only one variable and the curves are extended through the 100% speed point for comparing the results of the various hardware and operating parameter modifications.

Comparison of Table 5-13 and 5-14 data, DEI QCSEE-15 and QCSEE-16 operation, shows that the combined effect of the addition of the oil manifold cutouts, coupling baffle and the General Electric screen resulted in an increase in the heat generation. A data point showing this is the 6400 rpm, 66.3% torque and 91 kg/min (200 lb/min) oil flow rate operation where the heat rejection is 123 kW (165 hp) for QCSEE-15 and 130 kW (174 hp) for QCSEE-16 (6382 rpm). The effect of the individual modifications cannot be determined from the available test data.



OIL FLOW. . . . . 68 Kg/MIN (150 LB/MIN)
OIL IN TEMP . . . . 339°K (151°F)
SPEED . . . . 7000 RPM (88%)

SYMBOL	TORQUE	POWER
⊙	75%	8330 kW (11167 HP)
+	90%	9987 kW (13388 HP)
x	100%	10884 kW (14590 HP)

REFERENCE . . . . DEI QCSEE-18 OPERATION

Bearing and Oil Out to Oil In
Temperature Differentials - Variable Load

Figure 5.3-14. QCSEE Main Reduction Gear - OTW Test Unit

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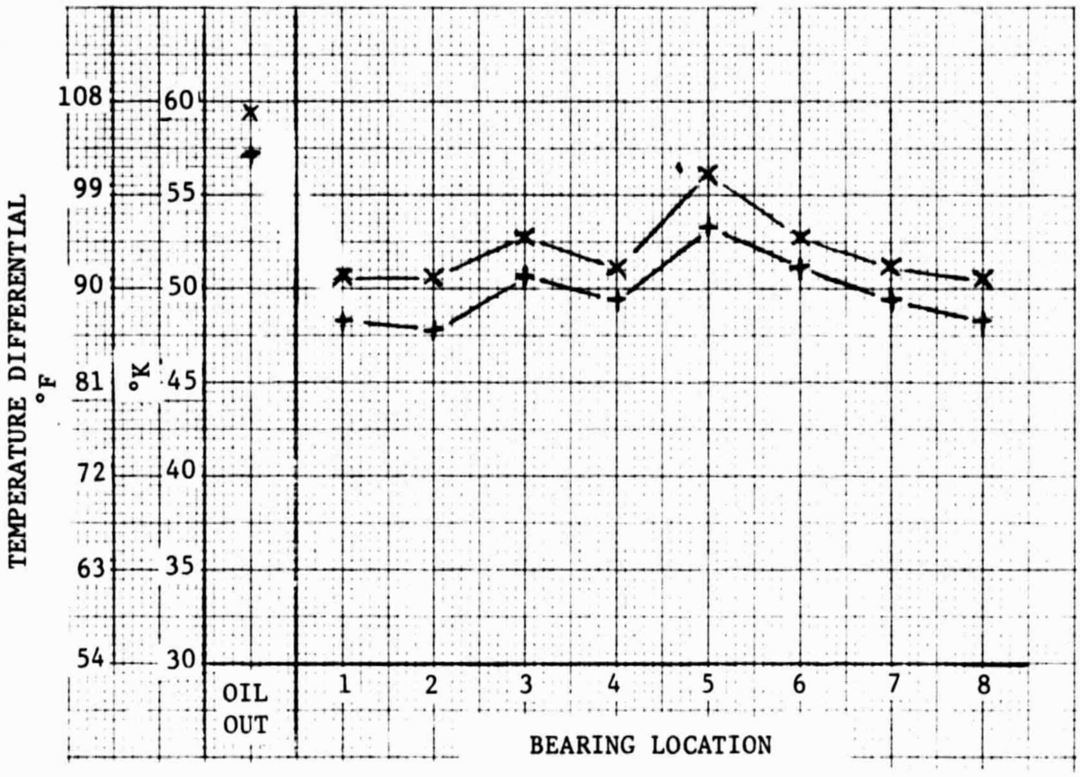
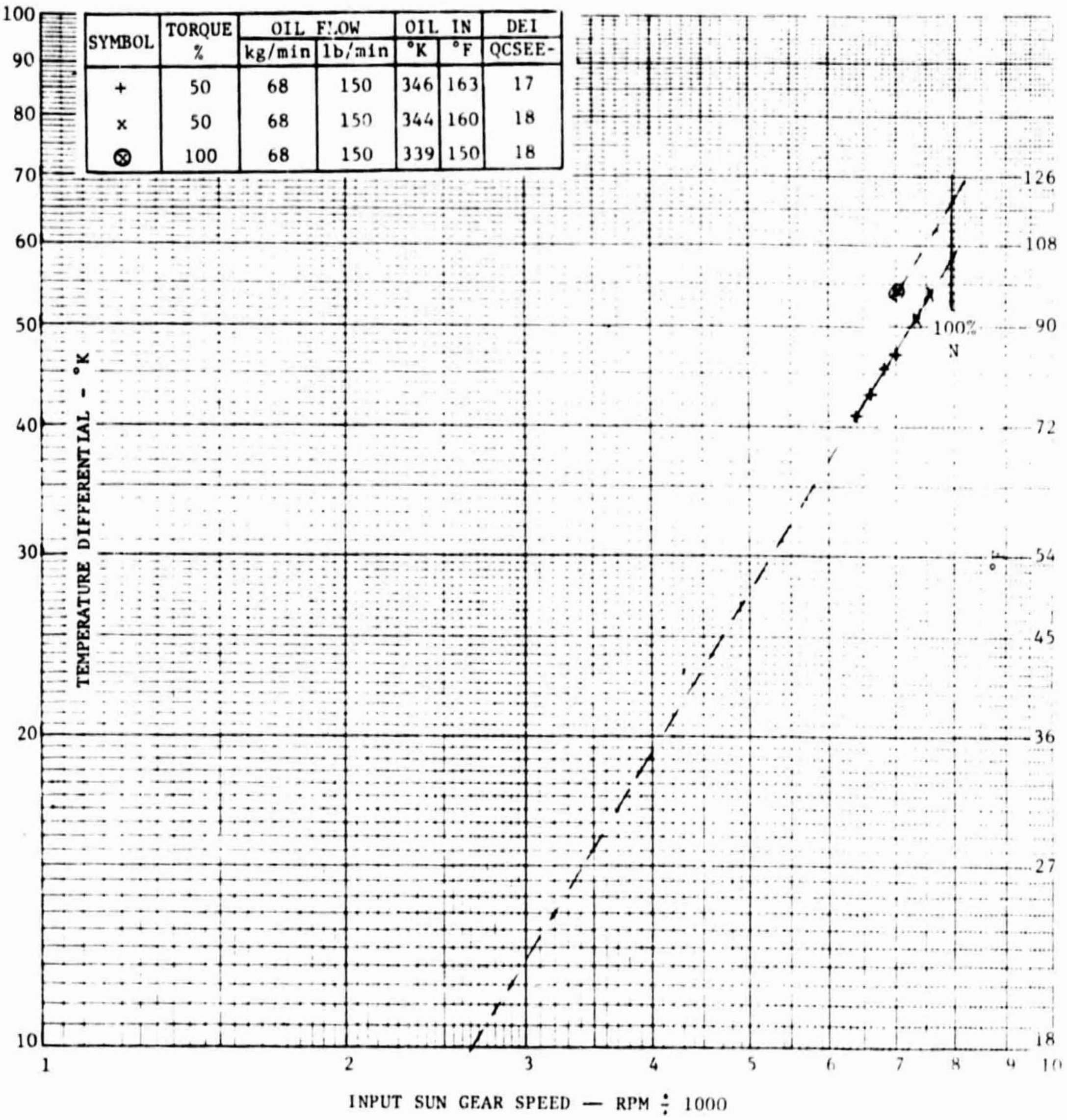


SPEED . . . . 7366 RPM (92.5%)
TORQUE. 50%
POWER . . . . 5844 kW (7834 HP)
OIL FLOW. . . . . 68 Kg/MIN (150 LB/MIN)
OIL IN TEMPERATURE -
x 340°K (152°F)
\+ 345°K (162°F)
REFERENCE . . . . DEI QCSEE-18 OPERATION

Bearing and Oil Out to Oil In Temperature
Differentials - Variable Oil Inlet Temperature

Figure 5.3-15. QCSEE Main Reduction Gear - OTW Test Unit



SYMBOL	TORQUE %	OIL FLOW		OIL IN		DEI
		kg/min	lb/min	°K	°F	QCSEE-
+	50	68	150	346	163	17
×	50	68	150	344	160	18
⊗	100	68	150	339	150	18

Figure 5.3-16. QCSEE Main Reduction Gear - OTW TEST UNIT Bearing to Oil In Temperature Differential

TABLE 5-13. QCSEE MAIN REDUCTION GEAR - OTW UNIT

DEI QCSEE-15 AND 15A TEST OPERATION

HEAT REJECTION AND EFFICIENCY

Inlet Oil Temperature . . . . 344-347°K (160-165°F)
Oil Type . . . . Aeroshell Turbine Oil 555
Oil Density . . . . .957 kg/l (8.00 lb/gal.)

Input Speed	Power		Torque	Oil Flow Rate		Heat Rej. Rate		Eff.
RPM	kW	Hp	%	kg/min	lb/min	kW	Hp	
3032	748	1003	15.6	114	250	28	38	.962
3032	748	1003	15.6	85	187	25	33	.967
5804	6095	8170	66.3	114	250	121	162	.980
5804	6095	8170	66.3	103	227	116	155	.981
5809	6100	8177	66.3	91	200	104	139	.983
5828	6120	8204	66.3	80	177	96	129	.984
6004	6304	8451	66.3	91	200	111	149	.982
6400	6720	9004	66.3	91	200	123	165	.982
6567	6786	9097	66.3	91	200	134	179	.980
6593	8242	11048	78.9	91	200	136	182	.984
6003	9485	12715	100	91	200	113	151	.988
6289	9958	13349	100	91	200	132	177	.987
6002	10325	13840	108.4	91	200	116	156	.989
6190	10648	14273	108.4	91	200	123	165	.988
6402	11012	14762	108.4	91	200	131	175	.988

TABLE 5-14. QCSEE MAIN REDUCTION GEAR - OTW UNIT

DEI QCSEE-16 TEST OPERATION

HEAT REJECTION AND EFFICIENCY

Inlet Oil Temperature . . . . 344-347°K (160-165°F)
Oil Type . . . . Aeroshell Turbine Oil 555
Oil Density . . . . .957 kg/l (8.00 lb/gal.)

Input Speed	Power		Torque	Oil Flow Rate		Heat Rej. Rate		Eff.
RPM	kW	Hp	%	kg/min	lb/min	kW	Hp	
3030	3182	4265	66.3	92	202	30	40	.991
4000	4200	5630	66.3	92	202	51	69	.988
5200	5461	7320	66.3	92	203	86	115	.984
6382	6701	8983	66.3	91	200	130	174	.981
6392	8524	11426	84	92	202	130	174	.985
4000	6321	8473	99.6	91	200	62	83	.990
5200	8216	11014	99.6	92	202	93	124	.989
6340	10391	13929	99.6	92	202	128	171	.988
6400	6720	9008	66.3	82	180	116	155	.983
6400	10113	13556	99.6	88	193	128	171	.988
6400	11009	14757	108.4	91	200	134	179	.988
6200	11057	14822	112.4	91	200	128	172	.988

TABLE 5-15. QCSEE MAIN REDUCTION GEAR - OTW UNIT

DEI QCSEE-17 TEST OPERATION

HEAT REJECTION AND EFFECIENCY

Inlet Oil Temperature . . . . 344-347°K (160-165°F)
Oil Type MIL-L-23699
Oil Density .967 kg/l (8.05 lb/gal.)

Input Speed	Power		Torque	Oil Flow Rate		Heat Rej. Rate		Eff.
RPM	kW	Hp	%	kg/min	lb/min	kW	Hp	
3021	3183	4267	66.3	68	150	29	39	.991
4000	4200	5630	66.3	68	150	46	62	.989
5200	5461	7320	66.3	68	150	72	97	.987
6400	6720	9008	66.3	68	150	108	145	.984
6400	5077	6806	50	68	150	104	140	.979
6600	5236	7019	50	68	150	112	150	.979
6800	5395	7232	50	68	150	117	157	.978
6980	5538	7424	50	68	150	122	163	.978
Reference: Note (1)								
6410	6730	9022	66.3	68	150	104	140	.984
6400	6720	9008	66.3	75	166	107	143	.984
6400	6720	9008	66.3	82	180	111	149	.983
6400	6720	9008	66.3	86	190	112	150	.983
6400	6720	9008	66.3	91	201	112	150	.983
Reference: Note (2)								
6400	6720	9008	66.3	68	150	105	141	.984
6400	6720	9008	66.3	75	166	107	143	.984
6400	6720	9008	66.3	82	180	107	144	.984
6400	6720	9008	66.3	86	190	110	148	.983
6400	6720	9008	66.3	89	195	111	149	.983

NOTE:

(1) Oil Flow to Reduction Gear - 68 kg/min (150 lb/min), Balance supplied to Inside Rotating Output Shaft Shroud.

(2) Oil Flow to Reduction Gear - 68 kg/min (150 lb/min), Balance supplied to Outside of Rotating Output Shaft.

TABLE 5-16. QCSEE MAIN REDUCTION GEAR - OTW UNIT

DEI QCSEE-18 TEST OPERATION

HEAT REJECTION AND EFFICIENCY

Inlet Oil Temperature . . . . 344-346°K (160-163°F)
Oil Type MIL-L-23699
Oil Density . . . . .967 kg/l (8.05 lb/gal.)

Input Speed	Power		Torque	Oil Flow Rate		Heat Rej. Rate		Eff.
RPM	kW	Hp	%	kg/min	lb/min	kW	Hp	
3000	3150	4223	66.3	68	150	29	39	.991
4000	4200	5630	66.3	68	150	48	64	.989
5200	5460	7319	66.3	68	150	77	103	.986
6400	6720	9008	66.3	68	150	110	148	.984
6400	5078	6807	50	68	150	109	146	.979
6800	5395	7232	50	68	150	118	158	.978
7000	5554	7445	50	68	150	126	169	.977
3031	3182	4266	66.3	92	203	34	45	.989
6400	6720	9008	66.3	92	202	130	174	.981
6800	7141	9572	66.3	92	202	145	195	.980
7000	7350	9853	66.3	92	202	153	205	.979
6400	5078	6807	50	68	150	107	143	.979
7000	5554	7445	50	68	150	124	166	.978
7378	5854	7847	50	68	150	136	182	.977
7000	5554	7445	50	68	150	124	166	.978
7366	5844	7834	50	68	150	137	184	.977
7554	5635	8034	50	68	150	144	193	.976

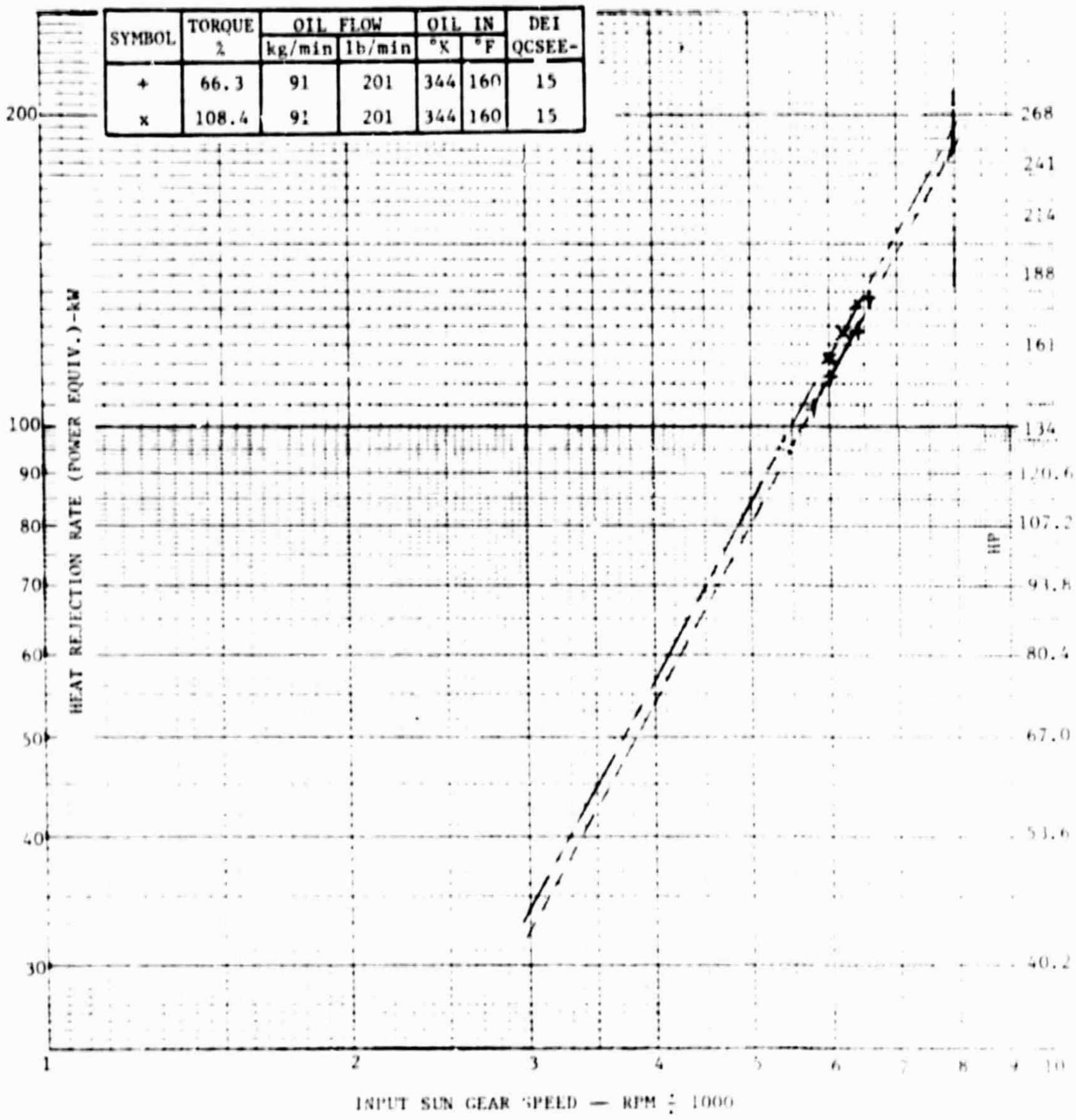
TABLE 5-17. QCSEE MAIN REDUCTION GEAR - OTW UNIT

DEI QCSEE-18 TEST OPERATION

HEAT REJECTION AND EFFICIENCY

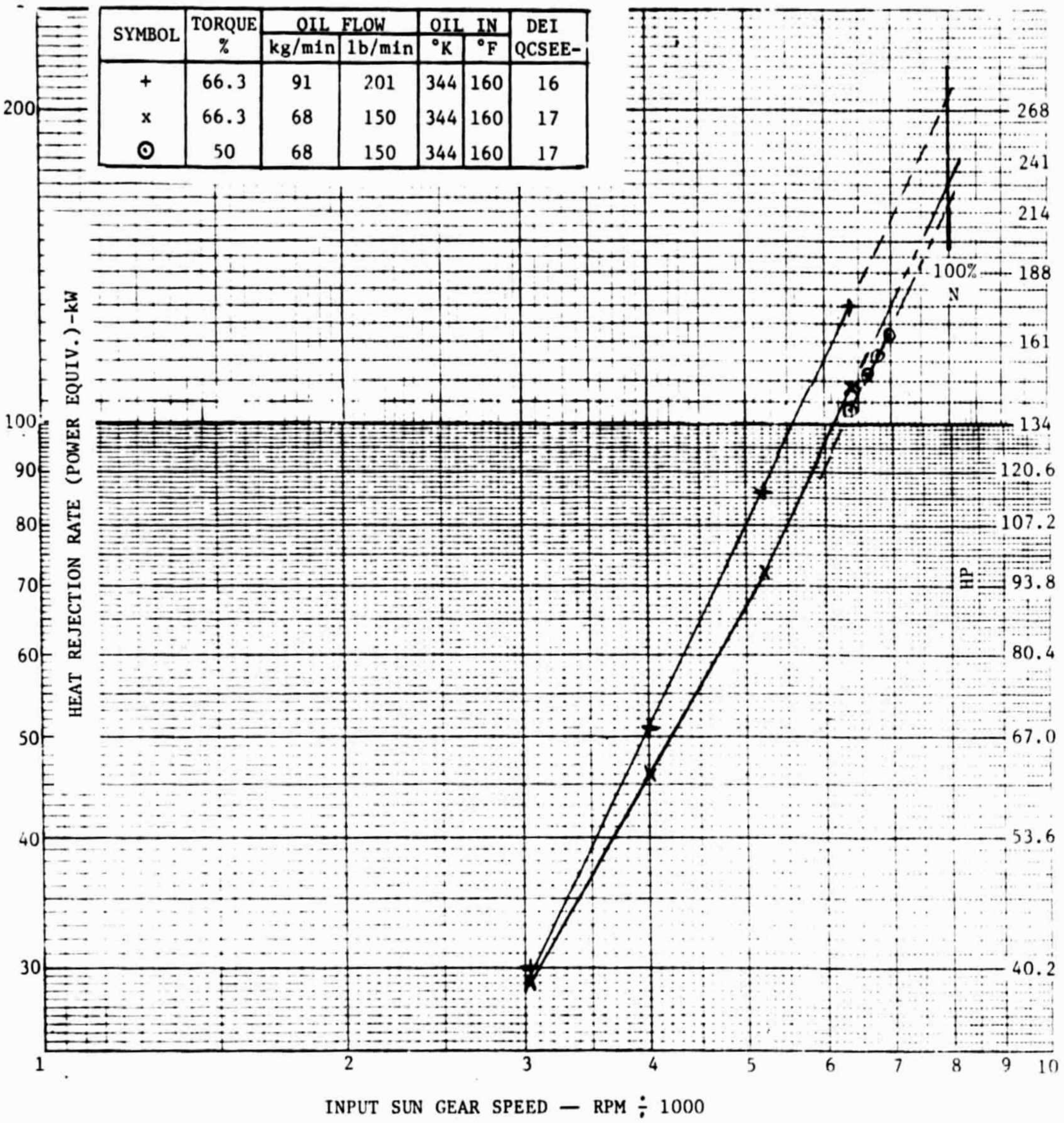
Inlet Oil Temperature . . . . 339°K (151°F)
Oil Type. MIL-L-23699
Oil Density . . . . .970 kg/l (8.09 lb/gal.)

Input Speed			Torque	Oil Flow Rate		Heat Rej. Rate		Eff.
RPM	kW	Hp	%	kg/min	lb/min	kW	Hp	
7000	8331	11167	75	68	150	132	177	.984
7000	9450	12668	85	68	150	134	179	.986
7000	9987	13388	90	68	150	134	180	.987
7000	10884	14590	100	68	150	137	184	.987
7148	11342	15204	100	68	150	144	193	.987
7359	5839	7827	50	68	150	141	189	.976
7365	8766	11750	75	68	150	144	193	.984



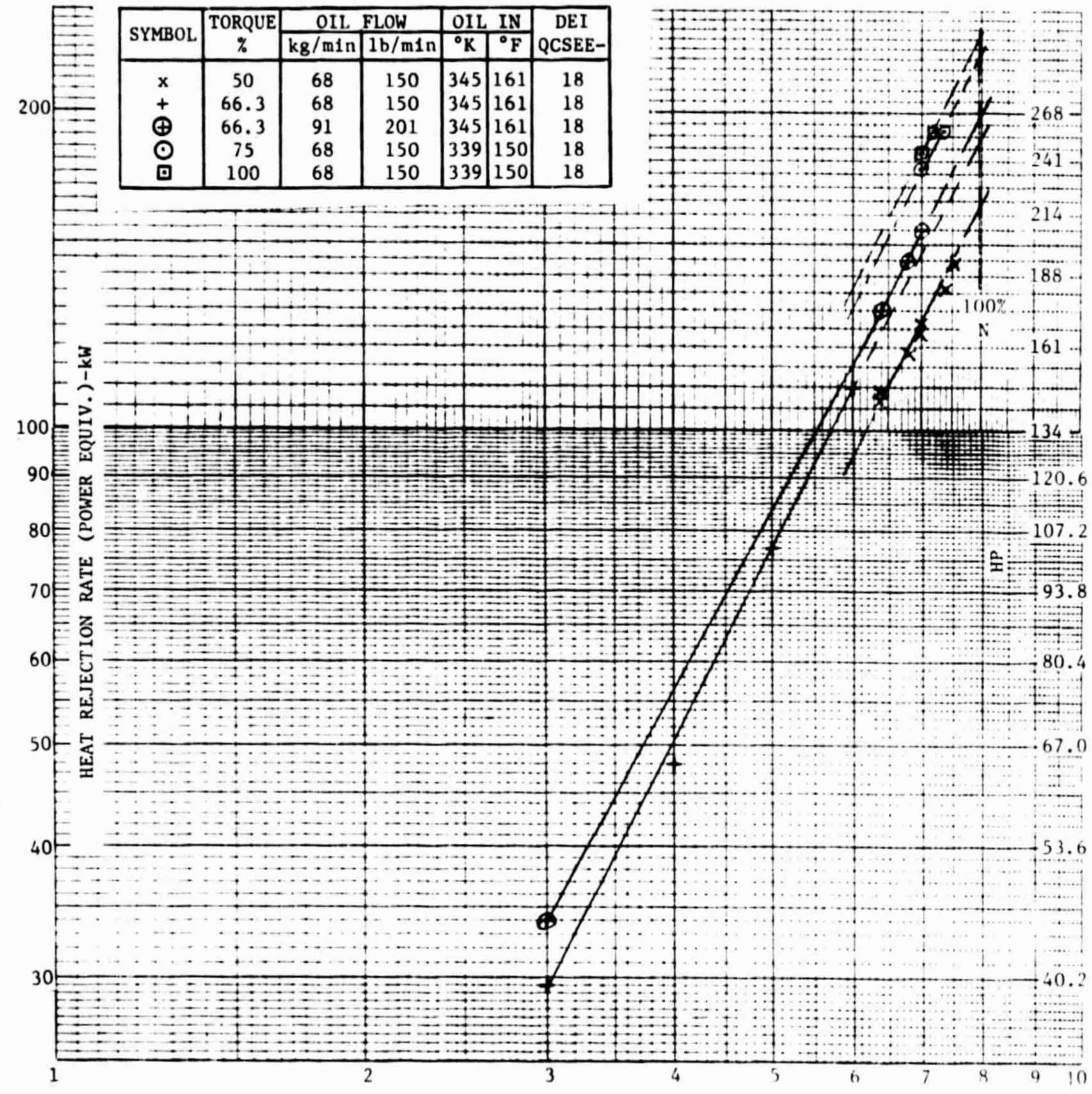
SYMBOL	TORQUE %	OIL FLOW		OIL IN		DEI
		kg/min	lb/min	°K	°F	QCSEE-
+	66.3	91	201	344	160	15
x	108.4	91	201	344	160	15

Figure 5.3-17. QCSEE Main Reduction Gear - OTW Test Unit Heat Rejection Rate Vs Speed



SYMBOL	TORQUE %	OIL FLOW kg/min	OIL FLOW lb/min	OIL IN °K	OIL IN °F	DEI QCSEE-
+	66.3	91	201	344	160	16
x	66.3	68	150	344	160	17
⊙	50	68	150	344	160	17

Figure 5.3-18. QCSEE Main Reduction Gear - OTW Test Unit
Heat Rejection Rate Vs Speed



SYMBOL	TORQUE %	OIL FLOW kg/min	OIL FLOW lb/min	OIL IN °K	OIL IN °F	DEI QCSEE-
x	50	68	150	345	161	18
+	66.3	68	150	345	161	18
⊕	66.3	91	201	345	161	18
⊙	75	68	150	339	150	18
⊡	100	68	150	339	150	18

Figure 5.3-19. QCSEE Main Reduction Gear - OTW Test Unit
Heat Rejection Rate Vs Speed

The most significant reduction in heat generation or power loss was accomplished by reduced oil flow to the gear unit.

The test operation during which additional oil was introduced directly into the reduction gear cavity, both inside and outside of the output shaft, to determine if inadequate scavenging from the lower part of the rig was responsible for the oil churning and heat generation produced an increase in heat generation but less than when the same total flow was supplied directly to the reduction gear inlet. Data for the added flows are shown in Table 5-15. At 6400 rpm, 66.3% torque, an increase in the total oil flow from 68 kg/min (150 lb/min) to 91 kg/min (201 lb/min) by adding the oil externally increased the heat rejection rate approximately one-third of that resulting from supplying a full 91 kg/min (200 lb/min) oil flow directly into the reduction gear. This indicates that oil churning by the output shaft is a contributor to the heat generation, but not the major source, at low speed (approximately 80%).

A comparison of 3000 rpm to 7000 rpm operation for DEI QCSEE-17 and QCSEE-18 shows a slightly higher heat rejection rate for the latter. The test parameter changes included removal of the General Electric screen, modification of the oil distribution ratio to the bearings and gears and installation of an oil scavenge pump. During the last test operation approximately 56% of the oil flow was to the gears whereas the amount was only 52% for the preceding test operation.

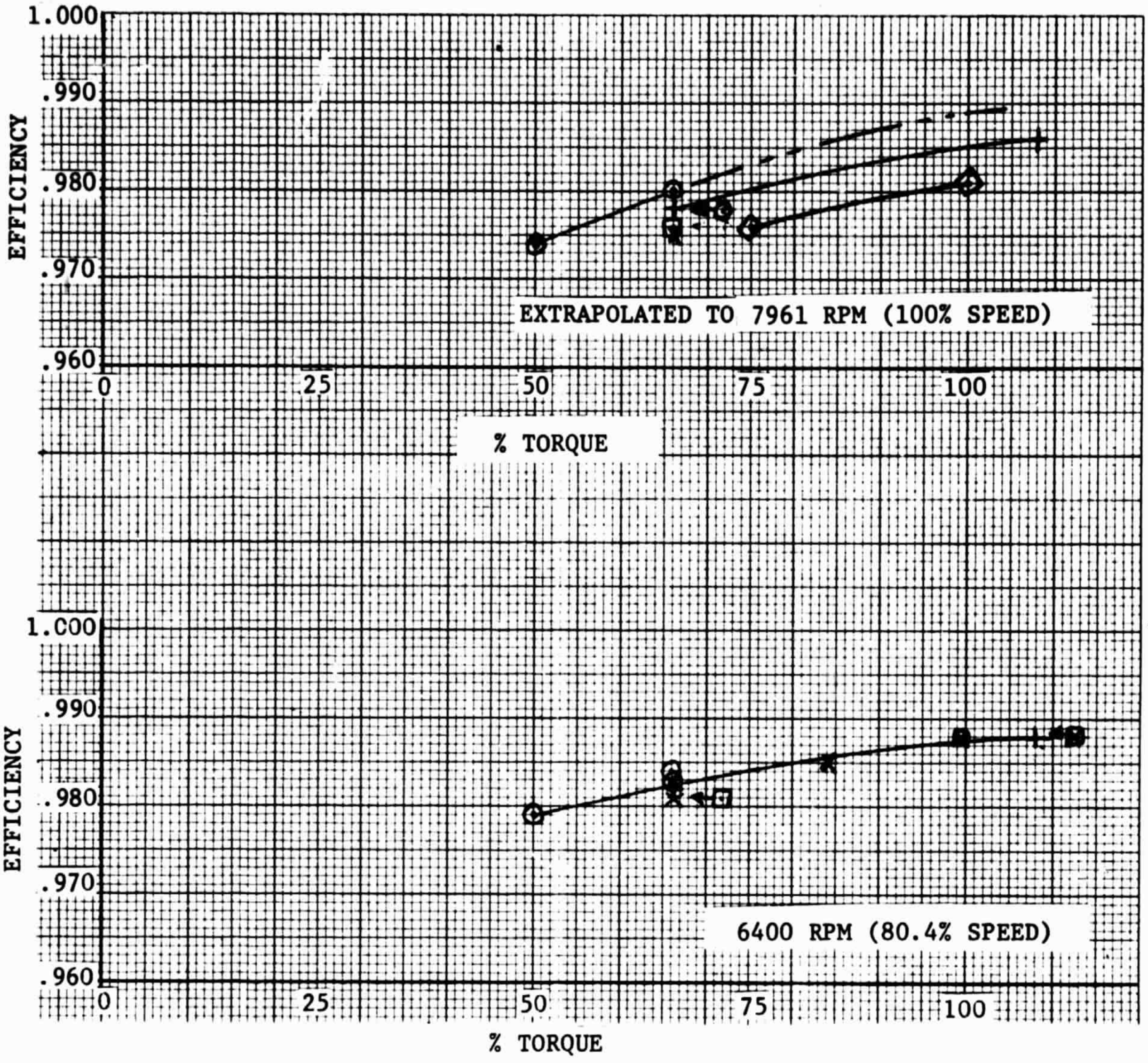
The reduction in the inlet oil temperature from 344°K (160°F) to 339°K (151°F) resulted in a small increase in the heat rejection rate as indicated by the 7366 rpm, 50% torque point data in Table 5-16 and 7359 rpm, 50% torque point in Table 5-17.

The slopes of the heat rejection rate versus speed curves presented by Figures 5.3-17 through 5.3-19 for the various operating conditions appear rather consistent. The curves have been extended to provide 6400 rpm and 7961 rpm data for use in the efficiency calculations.

Calculated efficiency versus percent torque is shown by Figure 5.3-20. The data for the points plotted are shown in Tables 5-18 and 5-19. The 6400 rpm data are mostly actual test points whereas all of the 7961 rpm data are from projections of the heat rejection versus speed curves. The maximum efficiency indicated at 6400 rpm is .988 at the 100% and 108% torques. At 7961 rpm the maximum efficiency point is .986 with an oil flow rate of 91 kg/min (200 lb/min). A projection of the lower oil flow rate data would show a slightly higher efficiency.

The maximum measured mechanical efficiency of 99.1% was obtained at low (approximately 26%) speed (3030 rpm). Measured mechanical efficiency decreased slightly with increased speed and increased slightly with increased torque. The maximum measured high speed, high power OTW mechanical efficiency was 98.7% at 90% speed and 100% torque.

The lower than anticipated efficiency is attributed to the churning of oil trapped in the roughly triangular space between adjacent star gears and the sun gear.



SYMBOL	DEI	OIL FLOW
+	QCSEE-15	91 kg/min @ 344°K (200 lb/min @ 160°F)
x	QCSEE-16	91 kg/min @ 344°K (200 lb/min @ 160°F)
⊠	QCSEE-16	88 kg/min @ 344°K (193 lb/min @ 160°F)
⊗	QCSEE-16	82 kg/min @ 344°K (180 lb/min @ 160°F)
⊙	QCSEE-17 & 18	68 kg/min @ 344°K (150 lb/min @ 160°F)
⊡	QCSEE-18	92 kg/min @ 344°K (202 lb/min @ 160°F)
◇	QCSEE-18	68 kg/min @ 339°K (150 lb/min @ 160°F)

Figure 5.3-20. QCSEE Main Reduction Gear - OTW Test Unit Efficiency Vs Torque

TABLE 5-18. QCSEE MAIN REDUCTION GEAR - OTW UNIT
HEAT REJECTION AND EFFICIENCY AT 6400 RPM (80.4% SPEED)

DEI QCSEE No.	Torque	Power		Oil In				Heat Rej.		Eff.	Symbol Figure 5.3-20
				Flow		Temp					
	%	kW	Hp	kg/min	lb/min	°K	°F	kW	Hp		
Ref	100	10141	13594	-	-	-	-	-	-	-	-
15	66.3	6720	9008	91	200	344	160	123	165	.982	+
	108.4	11012	14762	91	200	344	160	131	175	.988	+
16	66.3	6720	9008	91	200	344	160	130	174	.981	x
	84.	8534	11440	92	202	345	161	130	174	.985	x
	66.3	6720	9008	82	180	345	161	116	155	.983	⊗
	99.6	10120	13556	88	193	345	161	128	171	.988	⊠
	108.4	11009	14757	91	200	345	161	134	179	.988	x
17	66.3	6720	9008	68	150	345	161	108	145	.984	⊙
	50	5078	6807	68	150	344	160	104	140	.979	⊙
18	66.3	6720	9008	68	150	345	161	110	148	.984	⊙
	50	5078	6807	68	150	345	162	109	146	.979	⊙
	66.3	6720	9008	92	202	345	161	130	174	.981	⊡
	50	5078	6807	68	150	345	161	107	143	.979	⊙

TABLE 5-19. QCSEE MAIN REDUCTION GEAR - OTW UNIT
PREDICTED HEAT REJECTION AND EFFICIENCY AT 7961 RPM (100% SPEED)

DEI QCSEE No.	Torque	Power		Oil In				Heat Rej.		Eff.	Symbol Figure 5.3-20
				Flow		Temp					
	%	kW	Hp	kg/min	lb/min	°K	°F	kW	Hp		
Ref	100	12615	16910	-	-	-	-	-	-	-	-
15	66.3	8364	11211	91	200	344	160	185	248	.978	+
	108.4	13675	18330	91	200	344	160	195	261	.986	+
16	66.3	8364	11211	91	200	344	160	205	275	.975	x
17	66.3	8364	11211	68	150	344	160	170	228	.980	⊙
	50	6308	8455	68	150	344	160	162	217	.974	⊙
18	50	6308	8455	68	150	344	160	162	217	.974	⊙
	66.3	8364	11211	68	150	344	160	188	252	.978	⊙
	66.3	8364	11211	92	202	344	160	198	265	.976	⊡
	75.	9461	12683	68	150	339	151	225	302	.976	◈
	100	12615	16910	68	150	339	151	235	315	.981	◈

5.3.5 Vibratory Characteristics

Back-to-back testing of the QCSEE over-the-wing main reduction gear was conducted using the same basic system as for the under-the-wing reduction gear, preceding section 5.2.5.

The test setup consisted of a dynamometer driving a 1:3.3 speed increaser which drives the back-to-back gear units in the test rig through a torquemeter shaft. Figures 5.3-21 and 5.3-22 show the vibration monitoring instrumentation locations used for this testing.

The maximum observed vibration is shown in Table 5-20. Amplitude, input shaft rpm and predominant frequency are shown. The largest amplitude observed was star gear "wobble" as shown by proximity pickups 4 and 5. The frequency corresponded to ring gear first order. All other amplitudes were significantly lower and were not considered unusual.

TABLE 5-20. MAXIMUM OBSERVED VIBRATION - OTW

Pickup	Input rpm (%)	Amplitude Mils	Predominant Order
Proximity #3 Mid Shaft Radial	7000 (88) 7368 (92.5)	± 2.75	Ring, Sun
Proximity #4 Star Gear "Wobble"	7000	± 14.0	Ring
Proximity #5 Star Gear "Wobble"	7000	± 16.8	Ring
Proximity #12 Input Shaft Axial	7000	± 3.04	Sun Dyn, Star
Translational #6 Output F&A(Test Unit)	6400 (80)	± 2.96	Dyn, Ring Star, Sun
Translational - Pedestal Vertical	6800 (85)	± 3.2	Ring
Translational #1 Input Vertical (Slave)	6400 7000	± 1.0	Ring
Translational #2 Input Horizontal(Slave)	7000	± 1.98	Ring
Translational #4 Output Vertical (Test)	6400 7368	± 0.35	Ring, Star
Translational #5 Output Horizontal(Test)	7368	± 1.06	Star

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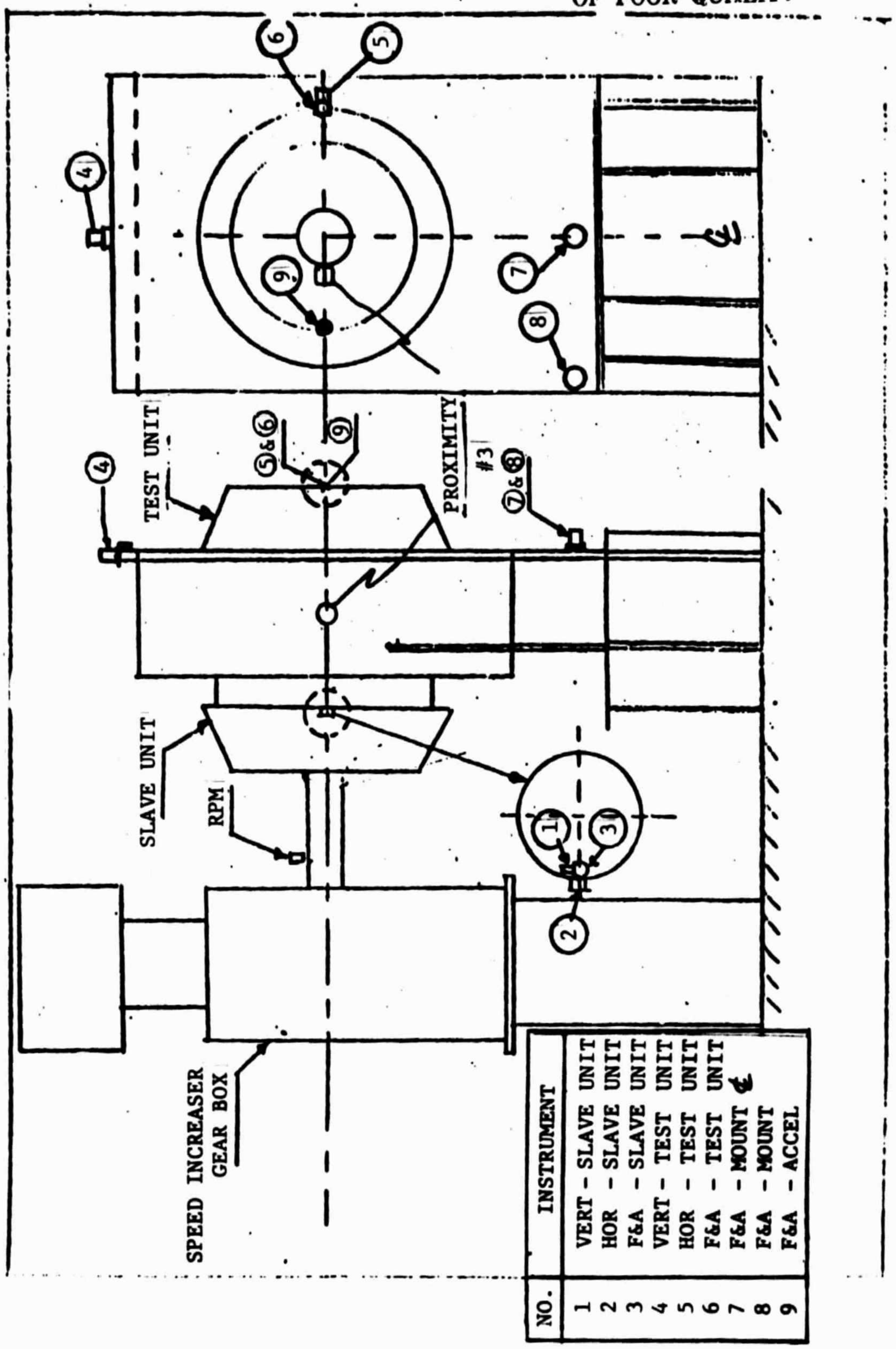

NO.	INSTRUMENT
1	VERT - SLAVE UNIT
2	HOR - SLAVE UNIT
3	F&A - SLAVE UNIT
4	VERT - TEST UNIT
5	HOR - TEST UNIT
6	F&A - TEST UNIT
7	F&A - MOUNT ℄
8	F&A - MOUNT
9	F&A - ACCEL

Figure 5.3-21. QCSEE Main Reduction Gear - OTW Vibration Instrumentation Locations

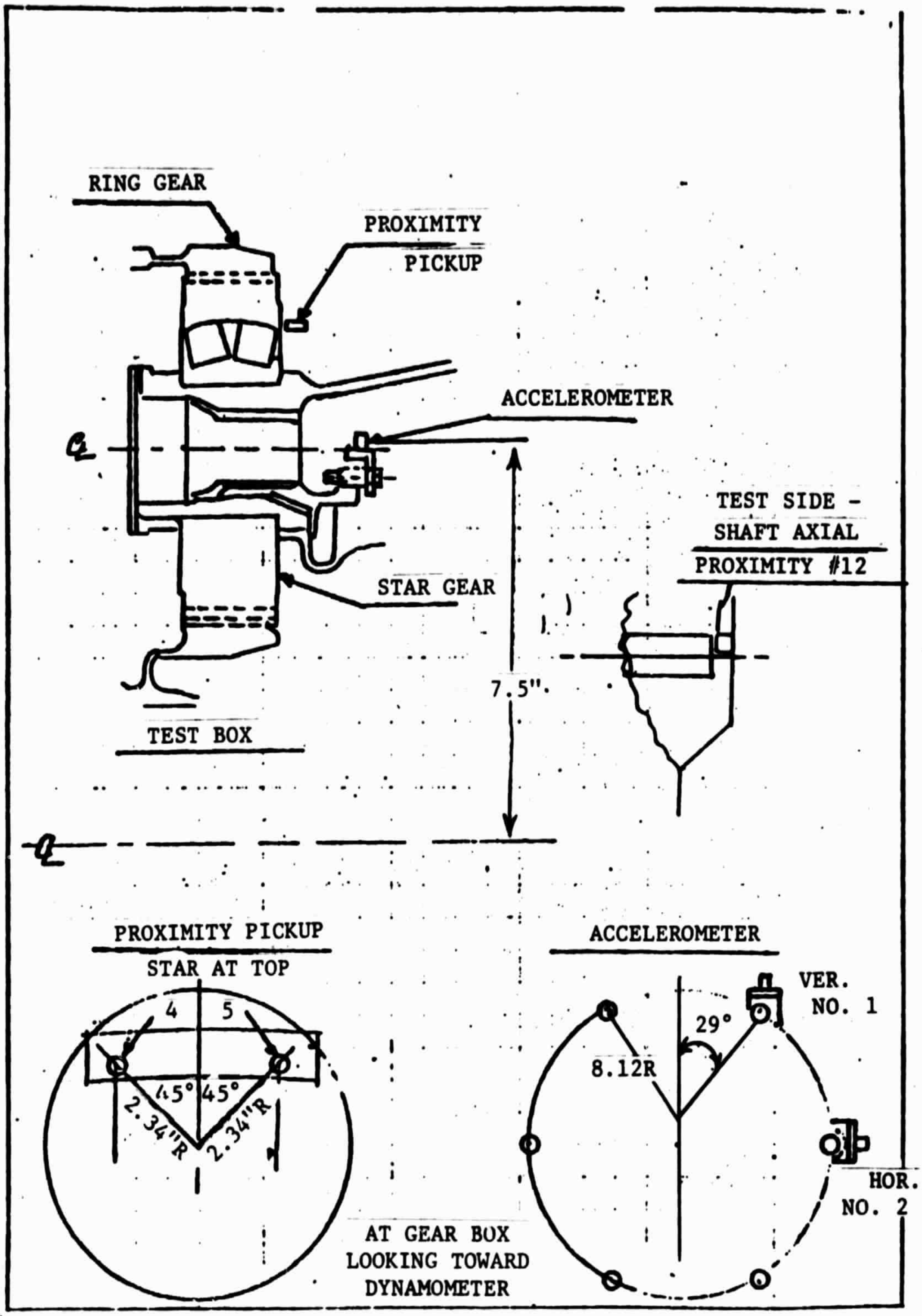

Figure 5.3-22. Main Reduction Gear - QCSEE OTW Proximity and Accelerometer Locations

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Star gear "wobble" as shown by proximity pickups 4 and 5 was analyzed in considerable detail in terms of sensitivity to load, speed and frequency of wobble.

Total amplitude at an input shaft speed of 7000 rpm is shown in Table 5-21. These results show that the largest amplitude of about 35 mils occurs at 50% design torque load. Total "wobble" amplitude as a function of input shaft speed is shown in Figure 5.3-23. The maximum amplitude occurs in the range of 7000 to 7300 rpm (88% to 92% speed).

Star gear wobble was further analyzed for frequency content. Results are shown in Table 5-22 and Figure 5.3-24. These results show the major component to be at first order of the ring gear. The next most significant frequency was first order of the star gear rotation with an amplitude one-fourth that of the ring gear order component.

Axial shaft motion relative to the test unit housing is shown in Figure 5.3-25. This also shows maximum response in the range of 7000 to 7300 rpm. The most significant frequency component was first order sun with the test stand drive motor and star gear first orders each contributing about one-half the amplitude of the sun component.

The drive motor vibration is evident in the translational motion of the housing and does not represent axial motion of the sun shaft.

The star gear wobble characteristics were considerably different than those observed for the UTW. It is recommended that this be monitored during engine testing. Wobble may be significantly different because of the difference in ring gear mounting between the engine and the back-to-back test installation.

Vertical, horizontal, forward and aft and mid-shaft vibration amplitudes are shown in Figures 5.3-26 and 5.3-27. Amplitudes of vertical and mid-shaft vibration are essentially the same order of magnitude as for the UTW Reduction Gear. Horizontal and fore and aft magnitudes are also generally similar except in the vicinity of 7000 rpm input shaft speed where the OTW is from 2 to 4 times the UTW magnitudes.

The differences in star gear wobble characteristics at the maximum amplitude condition for the OTW and those reported for the UTW Unit, Section 5.2.5., are shown by the following table.

Major	± Mils	
Component	OTW	UTW
Ring	18.7	5.2
Sun	3.7	5.2
Star	6.6	11.2

Except for the star gear wobble no unusual vibration conditions were observed. Since the ring gear support in the engine differs from that used in the test gear box it is recommended that provision be made to monitor this condition during actual engine testing.

TABLE 5-21. STAR GEAR WOBBLE PROXIMITY PICKUP #5 - OTW

Total Amplitude @ 7000 RPM (88%)

Date	% Torque	Total Amplitude - Mils
9-24-76	50	± 17.35
9-27-76	66	± 9.25
9-27-76	50	± 16.8
9-28-76	50	± 14.5
9-28-76	100	± 9.85
9-28-76	85	± 10.6

TABLE 5-22. STAR GEAR WOBBLE PROXIMITY PICKUP #5 - OTW ORDER RESPONSE VS LOAD & SPEED

		← Mils →				
RPM	% Torque	Ring	Sun	Sun + Ring	Star	Star + Ring
7000	50	± 13.2	± 3.7	± 6.6	± 5.0	
7368	50	± 18.7	± 3.3	± 3.7	± 3.3	
6400	50	± 5.3	± 0.8	± 1.1	± 3.5	
7000	50	± 8.3	± 2.4	± 4.7	± 3.7	
7368	50	± 4.7	± 1.9	± 4.2	± 2.6	
7554	50	± 3.7	± 1.7	± 3.7	± 2.1	
7000	75	± 9.4	± 0.5	± 0.5	± 2.6	
7368	75	± 5.9	± 1.9	± 3.3	± 6.6	
7000	85	± 10.5	± 0.5	± 0.7	± 3.1	
7000	100	± 7.9	± 0.6	± 0.5	± 1.9	± 1.1
7160	100	± 8.3	± 0.4	± 0.6	± 2.4	± 1.1

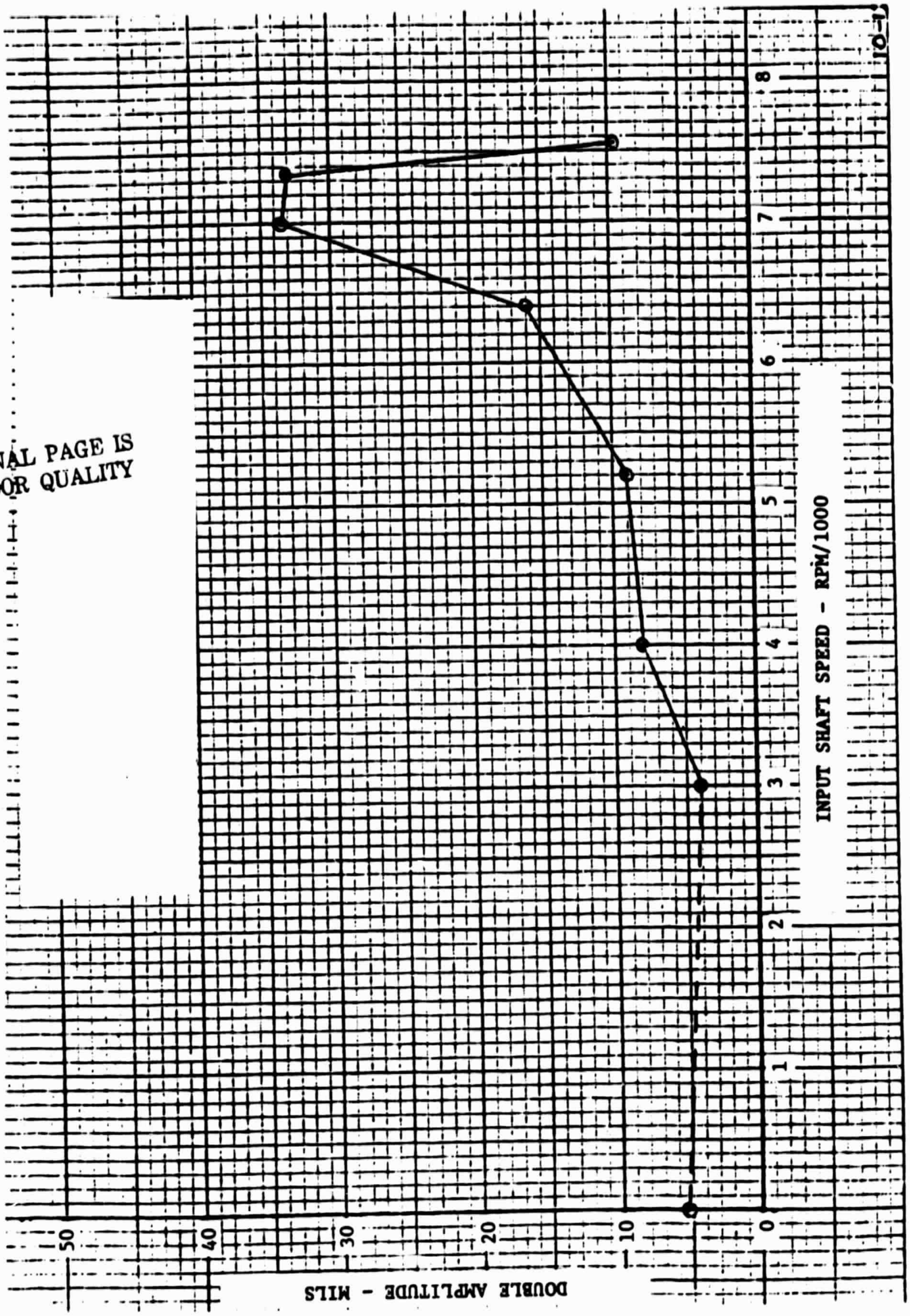


Figure 5.3-23. Proximity Pickup #5 Star Gear Wobble @ Pitch Line Maximum Total Amplitude Vs Speed - OTW Test Unit

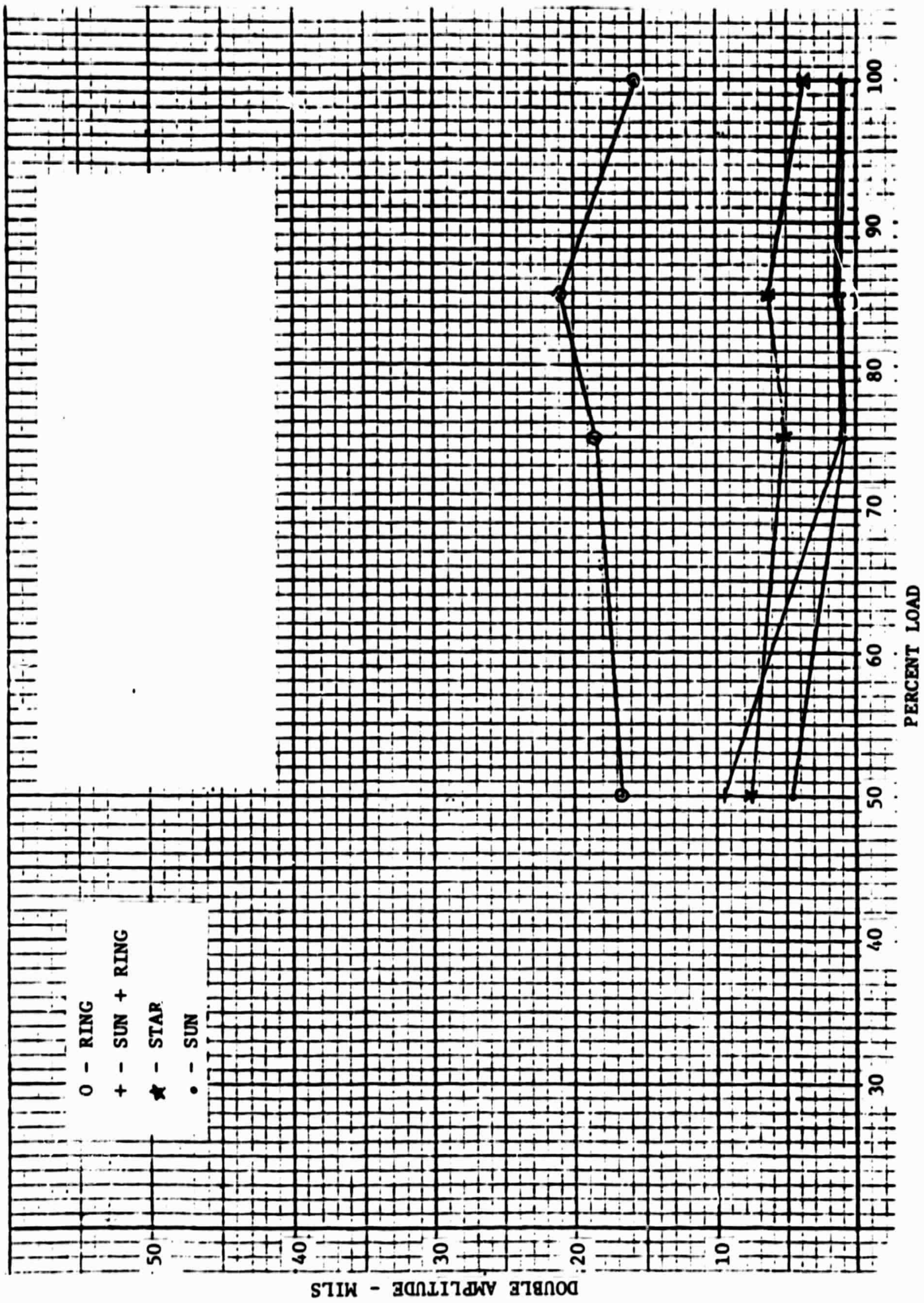
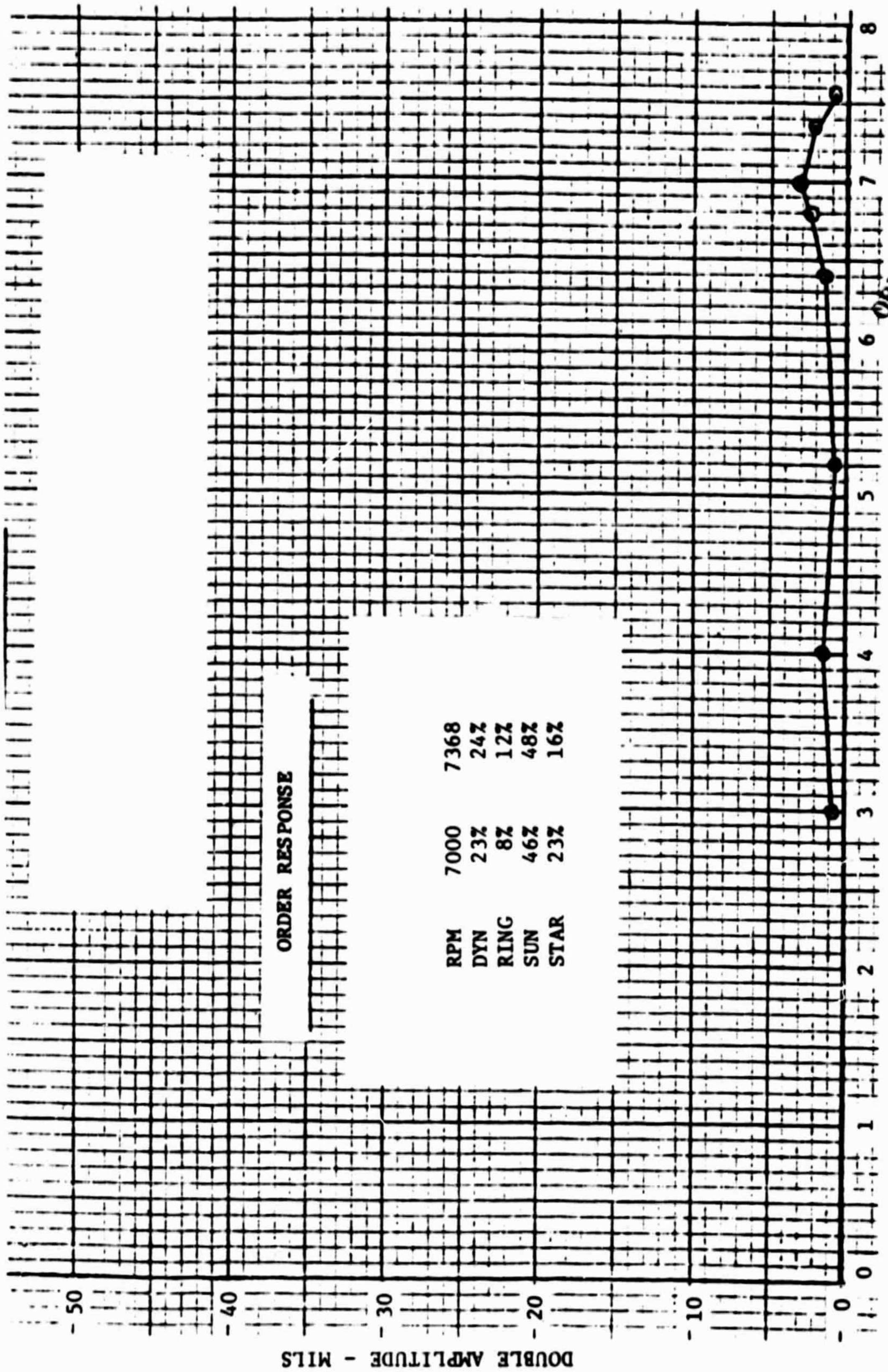


Figure 5.3-24. Proximity Pickup #5 Star Gear Wobble @ 7000 RPM Order Amplitude Vs Load - OTW Test Unit



RPM	7000	7368
DYN	23%	24%
RING	8%	12%
SUN	46%	48%
STAR	23%	16%

Figure 5.3-25. Proximity Pickup #12 Shaft Axial Motion Relative to Housing Maximum Total Amplitude Vs Input Speed - OTW Test Unit

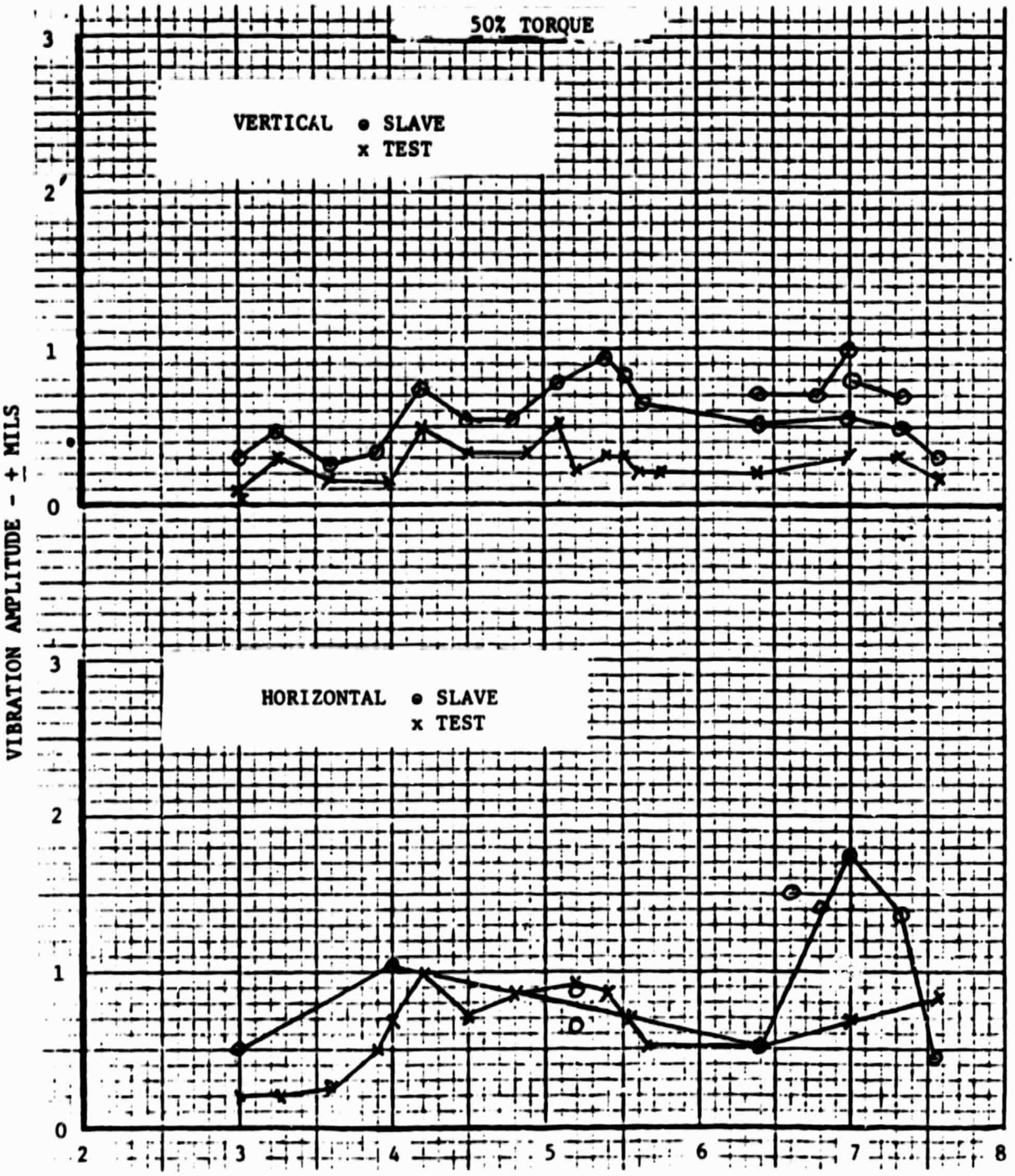


Figure 5.3-26. Main Reduction Gear - QCSEE - OTW
Vibration Amplitude Vs RPM @ 50% Torque

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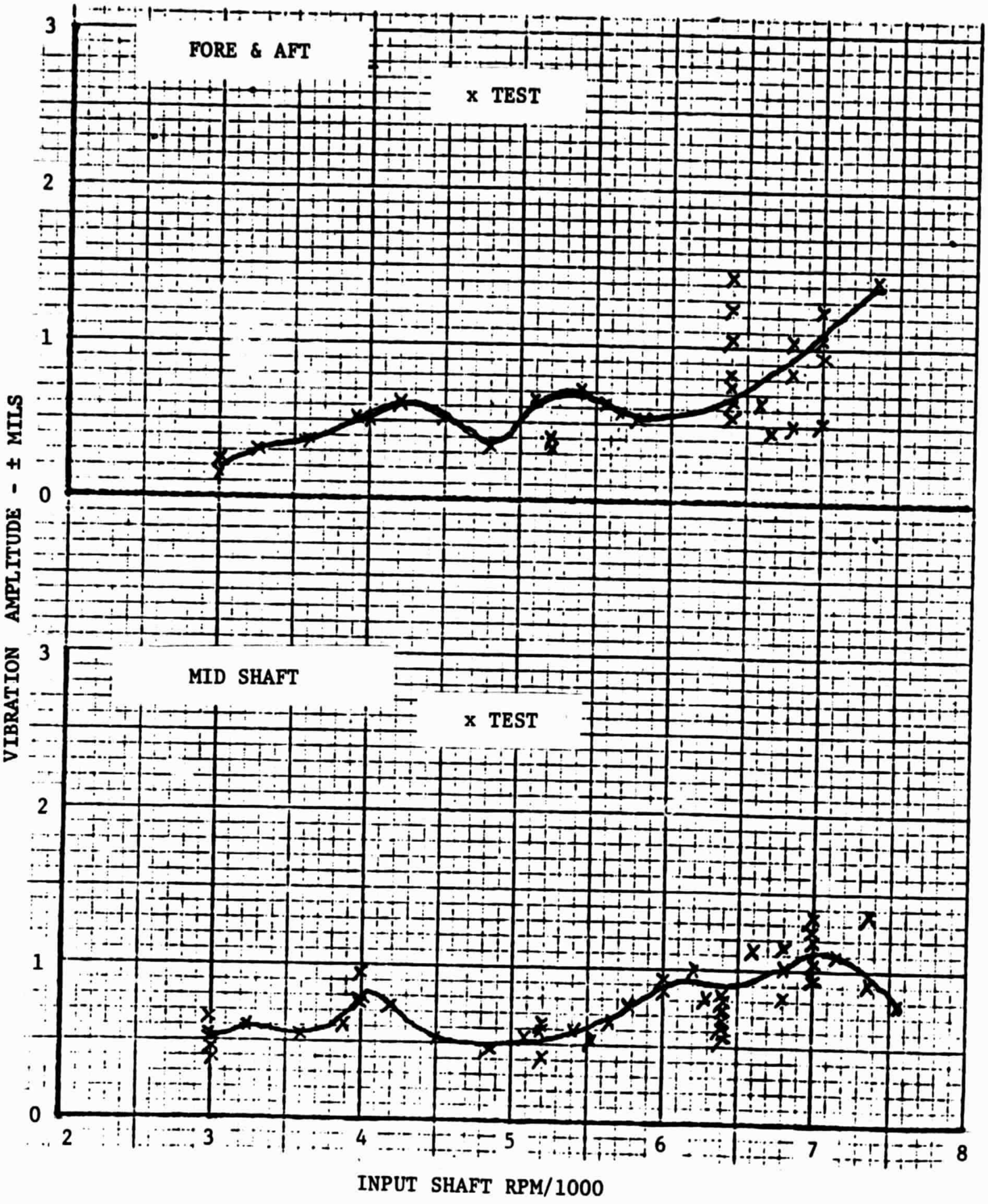

Figure 5.3-27. Main Reduction Gear - QCSEE - OTW
Vibration Amplitude Vs RPM

5.3.6 Post Test Inspection

At the conclusion of the reduction gear testing both the test unit and slave unit were completely disassembled and the following inspections performed.

a. Magnetic particle inspection of the following parts:

    Sun gears
    Ring gears
    Spray tubes
    Star gear supports
    Sun gear couplings

b. Fluorescent penetrant inspection of the following:

    Oil manifold (aluminum)

c. Visual inspection:

    All of the above parts
    Star gears and bearings

d. Measurements

    Star gear, sun gear and ring involute checks

The star gears could not be magnetic particle inspected without disassembly of the bearings, an operation requiring removal of more than half of the rollers from the cage pockets. The rollers in each bearing were visually inspected for indications of skidding at the inner end of the cylindrical surface. One roller was removed from each row of rollers in each bearing for inspection of the inner race for indications of distress. All bearings were found to be in good condition. No evidence of skidding type distress such as was encountered in some UTW unit star gear bearings was found.

No distress indications were found on any reduction gear parts by the magnetic particle or fluorescent penetrant inspections. A pressure test of the modified oil manifold showed leakage around some of the epoxy cement sealed cutout inserts. Since the oil manifold modifications did not show any significant improvement in test operation it has been recommended that the modified part not be installed in the engine.

Measurable wear was found on the flanks near the ends of the star gear teeth although wear at the center of the teeth was negligible, apparent evidence of the star gear wobble. The wear was relatively uniform at three points around the circumference of the gears.

Spectographic analysis performed on samples of oil taken from the test rig lubrication system at different times during the test operation was of limited value. The concentration of iron was 5, 4 and 10 parts per million (ppm) for three consecutive samples of oil taken during DEI QCSEE-18 test operation. The concentration of other elements in the oil remained relatively constant.

The condition of the OTW reduction gear units was judged acceptable for initial scheduled operation in the experimental engine. Monitoring of the reduction gear operation and inspections as frequently as possible consistent with the engine test program schedule is recommended.

The OTW reduction gears were delivered to General Electric Company, Aircraft Engine Group, at Evendale, Ohio for subsequent installation and test in the QCSEE OTW aircraft turbofan development engine.

5.4 Correlation of UTW and OTW Unit Performance

The general performance characteristics of the UTW and OTW reduction gears are similar. Differences in heat generation, bearing temperatures and efficiency are attributed to higher star gear speeds, higher gear pitch line velocities, smaller space between the star gears and the resultant entrapment of oil and increased oil churning in the OTW unit.

Bearing performance was acceptable although the UTW unit appeared to be marginal at some unidentified operating condition.

Gear tooth dynamic contact patterns were similar for both units.

The oil flow rate selected for the UTW was adequate although a lower flow rate may have been acceptable. The lowered flow rates for the OTW unit were acceptable for the conditions of operation.

The heat rejection rates were influenced more by speed than power and consequently the OTW unit with a higher output speed and gear pitch line velocity showed higher heat rejection and lower mechanical efficiency for comparable input speed and power.

The most significant vibratory characteristic identified is the star gear "wobble" which appeared to be more severe in the OTW unit than in the UTW unit. The factor directly influencing the star gears was not identifiable.

6.0 CONCLUSIONS

6.1 UTW Main Reduction Gears

UTW main reduction gears accumulated a total operating time of about 48.8 hours in the Hopkinson back-to-back test rig.

a. Satisfactory UTW maximum power operation was demonstrated at 100% design speed with 125% torque load, while transmitting a total power of 12,172 kW (16,316 hp).

b. Satisfactory maximum speed operation was demonstrated with 50% torque load up to 105% design speed, corresponding to a maximum gear pitch line velocity of 103 m/s (20,360 fpm), and a maximum star gear spherical roller bearing DN of 0.79×10^6 (based on bearing bore (stationary) in millimeters and outer race rotational speed in rpm).

c. UTW unit oil out temperature at 100% speed (7781 rpm), 100% power and 80 kg/min (177 lb/min) oil flow at 344°K (160°F) inlet temperature, based on test data shown in Table 5-2, is approximately 382°K (230°F).

d. UTW unit star gear bearing inner race temperature under above conditions is approximately 380°K (225°F), indicating probable churning of the oil after it leaves the bearing.

e. UTW unit mechanical efficiency under the above conditions is 98.9%. Oil churning is the probable major contributor to power loss or reduced efficiency.

f. At 125% power and conditions otherwise same as above, the UTW unit oil and bearing temperatures increase approximately 1°K (2°F) and mechanical efficiency is 99.1%. Overall reduction gear efficiency increases with increased torque up to 125% design torque. Power losses based on oil heat rejection rates are more dependent on speed than torque.

g. No natural frequencies were observed that significantly affect operation of the UTW reduction gear as operated in the test rig.

h. An observed star gear axial motion or "wobble" condition showed a maximum amplitude of about 15 mils (D.A.) at approximately 7500 rpm input shaft speed with 50% torque but decreased as speed increased. Star gear "wobble" motion also decreased with increasing transmitted torque. Predominant "wobble" frequency correlates with one per rev. of star gear rotational speed. Factors influencing the star gear "wobble" were not positively identified.

6.2 OTW Main Reduction Gears

OTW main reduction gears accumulated a total operating time of about 36 hours in the Hopkinson back-to-back test ring.

a. Satisfactory OTW maximum power operation was demonstrated at 90% design speed with 100% design torque, while transmitting a total power of 11,342 kW (15,204 hp).

b. Test rig power limitations restricted high speed, high power OTW operation.

c. Satisfactory OTW maximum speed operation was demonstrated with 50% torque load up to 95% design speed, corresponding to a maximum gear pitch line velocity of 112 m/s (22,300 fpm), and a maximum star gear spherical roller bearing DN of 0.85 x 10^6.

d. OTW unit oil out temperature at 100% speed (7960 rpm), 100% power and 91 kg/min (200 lb/min) oil flow at 344°K (160°F) inlet temperature, based on projection of test data as shown by Figure 5.3-6, is approximately 410°K (279°F). Descreasing inlet oil flow by about 25% to 68 kg/min (150 lb/min) would result in a projected oil outlet temperature of about 420°K (296°F), which is extremely high.

e. OTW unit star gear bearing inner race temperature under the design conditions in d. above is estimated to be approximately 5°K (9°F) lower than the oil temperature or 405°K (270°F) based on data shown in Figures 5.3-13 and 5.3-14. Decreasing the inlet oil temperature approximately 5°K (10°F) to 343°K (150°F) resulted in an average bearing temperature rise of about 2.2°K (4°F).

f. Maximum measured high speed, high power mechanical efficiency was 98.7% at 90% speed and 100% torque. Measured mechanical efficiency decreased slightly with increasing speed and increased slightly with increasing torque. The slightly lower than anticipated mechanical efficiency is attributed to the excessive churning of the oil in the roughly triangular area between adjacent star gears and the sun gear.

g. No natural frequencies were observed that significantly affect operation of the OTW reduction gear as operated in the test rig.

h. An observed OTW star gear axial motion or "wobble" condition showed greatest amplitude of about 35 mils (D.A.) at approximately 7000 to 7300 rpm (88 to 92% N) input shaft speed with 50% torque, but decreased rapidly as speed increased. Predominate "wobble" frequency correlates with a one per rev of the ring gear rotational speed. OTW star gear "wobble" appears to be more severe than was the UTW. As noted for the UTW unit, factors influencing the OTW unit star gear "wobble" were not positively identified.

i. OTW unit opwerated satisfactorily in the test rig at 7000 rpm, (88% N), 100% torque and a reduced oil flow of 68 kg/min (150 lb/min) at 339°K (151°F) inlet temperature.

j. Gear scoring was not apparent from any of the test rig operation.

7.0 RECOMMENDATIONS

1. Monitor bearing temperatures, reduction gear vibratory characteristics and star gear "wobble" during engine operation for correlation with the test rig operating experience.

2. Supply 91 kg/min (200 lb/min) oil flow at 338°K (150°F) to the OTW reduction gear in the engine.

3. Conduct development effort to identify and analyze factors influencing the star gear "wobble".

4. Conduct development effort to devise and test methods for directing the oil from the sun gear/star gear area to reduce oil churning and heat generation and improve efficiency.

5. Continue investigation to determine the minimum oil flow required for satisfactory lubrication of the gears.

8.0 REFERENCES

1. Quiet Clean Short-haul Experimental Engine (QCSEE) Under-the-Wing (UTW) Final Design Report, NASA CR-134847.
2. Quiet Clean Short-haul Experimental Engine (QCSEE) Over-the-Wing (OTW) Final Desing Report, NASA CR-134848.
3. General Electric Company, Aircraft Engine Group Specification M50TF1672-S1 dated September 9, 1975, Gear Assembly, Speed Decreaser.
4. Quiet Clean Short-haul Experimental Engine (QCSEE) Main Reduction Gears Detailed Design Final Report, NASA CR-134872.
5. Quiet Clean Short-haul Experimental Engine (QCSEE) Main Reduction Gears Bearing Development Program Final Report, NASA CR-134890.

APPENDIX A

ASSEMBLY PROCEDURE QCSEE A-1, UTW STAR GEAR AND SUPPORT SUBASSEMBLY

QCSEE MAIN REDUCTION GEAR - UTW UNIT

ASSEMBLY PROCEDURE
FOR
UTW STAR GEAR AND SUPPORT SUBASSEMBLY

DATE: OCT. 31 1975

APPROVALS:

Design

Assembly

Test

Test Equipment

Instrumentation

Project

POWER SYSTEMS GROUP
CURTISS-WRIGHT CORPORATION
WOOD-RIDGE, N. J.

QCSEE MAIN REDUCTION GEAR - UTW UNIT

Assembly Procedure for Star Gear and Support Subassembly (for Test Rig Operation)

1. Parts Required:

1.1 Reduction Gear Hardware:
Reference: LS 34810 Layout and Bill of Material No. 210

Det. No.	Part Number	Name	Quantity	Check
32	MS9388-011	O-Ring	6	
6	MS9388-029	O-Ring	6	
26	MS9388-032	O-Ring	6	
15	MS9557-12	Bolt	6	
16	AN960C416L	Washer	6	
28	764D107	Bolt	12	
29	2067D960	Tablock	12	
31	185144	Spray Bar	6	
25	185147	Oil Sleeve	6 (Note 1)	
18	185148	Brg. Nut	6	
19	185149	Nut Lock Ring	6	
5	185151	O-Ring	1	
8	185152	O-Ring	1	
20	185154	Retaining Ring	6	
21	185155	Retaining Ring	6	
3	185157	Star Gear & Brg. (See 2.2)	6	
A2	490640	Oil Manifold Assy.	1	
A1	490643	Star Gear Support Assy.	1	

Note 1: Two pieces P/N 185147 replace two pieces P/N 185179 for test rig operation.

2.4 Place P/N 490643 support on bench with trunnions up.

Chill trunnions with dry ice.

2.5 Heat the gear and bearing units in oven to 250°F.

2.6 With bearing S/N facing up, place gear and bearing on chilled trunnion making sure that bearing inner race face is seated against the trunnion shoulder.

2.7 Repeat for remaining gear and bearing units. Record bearing S/N, trunnion location, bearing internal radial looseness code appearing on the bearing and the bearing bore (Quality Lab Report).

Trunnion No.	Brg. S/N	IRL	Bore
1			
2			
3			
4			
5			
6			

2.8 Place thermocouple instrumented P/N 185150 simulated VPM support on the trunnions.

2.9 Install P/N 185148 bearing nuts and tighten to 375-415 ft-lbs torque. Inspect between bearing face and support shoulder with .001 feeler gage to verify that bearing is against the shoulder.

2.10 Install P/N 185149 nut lock rings and P/N 185154 retaining rings. Check that retaining rings are fully seated in the groove.

2.11 Install P/N MS9388-029 O-rings in smaller diameter grooves and P/N MS9388-032 O-rings in larger diameter grooves on the P/N 185147 oil sleeves. Coat O-rings with Lubriplate grease before installing.

2.12 Insert an oil sleeve with O-rings in each trunnion and install P/N 185155 retaining rings. Check that retaining rings are fully seated in the groove.

2.13 Assemble a P/N MS9388-011 O-ring on each of the six P/N 185144 spray bars. Lubricate O-ring with Lubriplate grease before installing.

1.2 Test Rig Parts

Reference: LS 34822 and Bill of Material No. 212

Det. No.	Part Number	Name	Quantity
93	185150	Simulated VPM Support (Instrumented per ES 164342)	1
15	185187	Pilot Ring	1
16	185213	Nut Ring	1
	185235	Cover Plate	2
		Gasket (make at Assy.)	2
117	MS35456-35	Screw	3
	7640107	Bolt	4
	2067D960	Tablock	4

2.0 Assembly Instructions

References: Dwgs. 490644, 490645, LS 34822 and T/L 244

2.1 Clean all parts thoroughly, check all passages and recesses and protect in plastic bags until ready to be used.

2.2 Select 6 P/N 185157 gear and bearing units having approximately the same internal radial looseness.

2.3 Number the star gear trunnions on P/N 490643 star gear support assembly starting with No. 1 at the 12 o'clock position (approx. in line with the offset hole in the mounting flange) and proceeding counterclockwise. Vibroetch number on O.D. of bearing back-up flange. Record trunnion diameters (Quality Lab Report). Record support serial number.

Support S/N ______________

Trunnion No.	Trunnion Dia.
1	____________
2	____________
3	____________
4	____________
5	____________
6	____________

2.14 Assemble the six spray bars into the P/N 490640 oil manifold using the 2067D960 tablocks and 764D107 bolts. Bolt torque is 80-85 in-lbs. ____________

2.15 Install P/N 185151 O-Ring in the larger diameter groove and P/N 185152 O-Ring in the smaller diameter groove of P/N 490640 oil manifold. Coat O-Rings with Lubriplate grease before installing. ____________

2.16 Invert star gear support and install oil manifold. Attach with the P/N MS9557-12 bolts and AN960C416L washers. Bolt torque is 80-85 in-lb. ____________

2.17 Attach P/N 185187 pilot ring using P/N 185213 nut ring and the three MS 35456-35 screws in locations shown on LS 34822, sheet 1. Torque is 120-130 in-lb. ____________

2.18 Install compression fitting in P/N 185187 pilot ring and thread thermocouple leads through the fitting. ____________

2.19 Install P/N 185235 plates with gasket on the two opening pads on the oil supply side of the oil manifold. Use two P/N 764D107 bolts and two 2067D960 tablocks per plate. Bolt torque is 80-85 in-lbs. ____________

2.20 Cover unit with plastic to protect from contamination while awaiting installation into the test rig. ____________

APPENDIX B

ASSEMBLY PROCEDURE QCSEE A-2, UTW SUN GEAR SUBASSEMBLY

QCSEE A-2

QCSEE MAIN REDUCTION GEAR - UTW UNIT

Assembly Procedure
for
UTW Sun Gear Subassembly

DATE: OCT. 31 1975

APPROVALS:

Design
Assembly
Test
Test Equipment
Instrumentation
Project

Power System Group
Curtiss-Wright Corporation
Wood-Ridge, N. J.

QCSEE Main Reduction Gear - UTW Unit

Assembly Procedure for Sun Gear Subassembly
(For Test Rig operation)

1. Parts required (for one sun gear assembly)

1.1 Reduction Gear Hardware:
(Reference: LS 34810 and Bill of Material No. 210)

Item	Part Number	Name	Qty.	Check
A5	490642	Sun Gear Assembly	1	
22	185146	Ring, Sun Gear & Coupling Lock	1	
23	185140	Coupling, Turbine Output Shaft	1	
9	675D4	Bolt (.3125-24 UNJF-3A)	32	
10	185153	Nut (.3125-24 UNJF-3B)	32	
33	MS9677-09	Bolt (.250-28 UNJF-3A)	4	

Rig parts: (Reference LS 34822 and Bill of Material No. 212)

Item	Part Number	Name	Qty.	Check
46	185174	Coupling, Turbine Shaft Input	1	

1.2 Clean all parts thoroughly ______

1.3 Assemble the P/N 490642 sun gear assembly on the P/N 185140 coupling, engaging the splines such that the ellipse mark on the internal spline tooth end face of the P/N 490642 sun gear assembly is between the two ellipse marks on the external spline teeth end face of the P/N 185140 coupling. ______

Check

1.4 Install the P/N 185146 lock ring on the P/N 185140 coupling by inserting the eight internal lugs on P/N 185146 lock ring through the eight external slots in the spline teeth of P/N 185140 coupling until the lugs on the P/N 185146 lock ring are engaged in the O.D. groove in the P/N 185140 coupling. Rotate the P/N 185146 lock ring until the offset hole in the flange of the P/N 185146 lock ring is aligned with the offset hole in the flange of the P/N 490642 sun gear.assembly. __________

1.5 Install the four P/N MS9677-09 bolts to fasten the P/N 185146 lock ring to the P/N 490642 sun gear assembly, and torque the bolts to 80-85 in.-lbs. __________

1.6 Install the P/N 185174 coupling on the P/N 185140 coupling with the internal splined hub of the P/N 185174 coupling projecting through the I.D. of the P/N 185140 coupling. Use thirty-two P/N 675D4 bolts and thirty-two P/N 185153 nuts to fasten the two couplings at the large flange faces. Torque the nuts to 435-441 in.-lbs. __________

1.7 Unless otherwise noted, lubricate parts at assembly with MIL-L-23699 oil. __________

1.8 Cover unit with plastic to protect from contamination while awaiting installation into the test rig. __________

APPENDIX C

ASSEMBLY PROCEDURE QCSEE A-3, UTW UNIT TEST RIG

QCSEE MAIN REDUCTION GEAR - UTW UNIT

ASSEMBLY PROCEDURE
FOR
UTW UNIT TEST RIG

DATE: OCT. 3 1 1975

APPROVALS:

- Design
- Assembly
- Test
- Test Equipment
- Instrumentation
- Project

POWER SYSTEMS GROUP
CURTISS-WRIGHT CORPORATION
WOOD-RIDGE, N. J.

QCSEE A·3

QCSEE MAIN REDUCTION GEAR - UTW UNIT

Assembly Procedure for UTW Test Rig (for Test Rig Operation)

1.0 Main Housing Sub-Assembly

Rig Parts: (Reference LS34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
74	185191	Bearing (Kaydon)	1	
5	185201	Cyl. Support, Front	1	
35	185202	Brg. Retainer	1	
A2	490657	Intermed. Hsg. & Flange Assy.	1	
A1	490661	Center Hsg. & Support Assy.	1	
109	RA011205C104	Bolt, 3/8-16 x 1-1/4	54	
112	RA021205P112	Bolt, 3/8-24 x 1-3/4	20	
127	RA301209C000	Lock Washer, 3/8	54	
222	2067D970	Tablock Washer	10	
70	185195	O-Ring, 26.000 I.D. x .139 CS	1	
219	RA570809C006	Dowel Pin, 1/8 O.D. x 3/8 Lg.	4	

Assembly Fixtures:

928619-7	Support Legs (Channel)	2
928619-1	Support Legs (Tubular)-30"	2
928619-4	Support Legs (Tubular)-33 7/8"	2
	Bolt - 3/4-10 x 2-1/2	2
	Bolt - 7/16-14 x 2-1/2	4
	Bolt - 3/4-10 x 1-1/2	4
	Nut - 3/4-10	4
AN960-416	Washer - 3/4 Bolt Size	10
	Washer - 7/16 Bolt Size	4

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1.1 Clean all parts thoroughly

1.2 Raise the P/N 490661 Center Hsg. and Flange Assy. and attach channel support legs to base. The hole 28-3/8 inches from the end of the channel mates with the hole in the outer flange of the base on the lifting plate end of the housing. The channels bolt to outermost holes in the transverse base members using the 3/4-10 x 1-1/2 bolts and 3/4-10 nuts. __________

1.3 Attach the two P/N 928619-1 30" long tubular legs to the anti-drive end side of the lifting plate using the two 3/4-10 x 2-1/2 bolts and two 3/4 plain washers. __________

1.4 Attach the two P/N 928619-4 33-7/8 long tubular legs to the drive end side of two hydraulic cylinder attachment arms on the upper side of the housing using two 7/16-14 x 2 1/2 bolts and two 7/16 plain washers for each leg. __________

1.5 Position housing with axis vertical and anti-drive end down. __________

1.6 Assemble P/N 185191 bearing into P/N 185202(ND) bearing retainer. Lubricate bearing I.D. with Lubriplate grease and press into P/N 185202(ND) bearing retainer (Fit is .0000-.0025 tight.) __________

1.7 Install P/N 185195 O-Ring (26.000 I.D. x .139 CS) in the groove in P/N 490661(ND) center housing and support assembly. Coat the O-Ring surface, and the face of the P/N 490661 center housing and support assembly that mates with the P/N 185201(ND) cylinder front support with lubriplate grease. __________

1.8 Install the P/N 185201(ND) cylinder front support on the P/N 490661(ND) center housing and support assembly. __________

1.9 Coat the P/N 185191 bearing O.D. with Lubriplate grease and install the P/N 185202(ND) bearing retainer, with P/N 185191 bearing installed, into the P/N 185201(ND) cylinder front support (Fit is .0000-.0026 loose). __________

1.10 Install four P/N RA570809C006 dowels in the P/N 490661 center housing and support assembly. __________

1.11 Install twenty P/N RA021205P112 bolts and ten P/N 2067D970 tablock washers to attach the P/N 185202(ND) bearing retainer to the P/N 490661 center housing and support assembly. Leave the two holes at the top & two holes at the bottom of the P/N 490661 center housing and support assembly open for subsequent attachment of the P/N 490665 brush block housing bracket assemblies. Torque the twenty bolts to 215-235 in.-lbs. __________

1.12 Attach the P/N 490657(ND) intermediate housing and flange assembly to the P/N 185201(ND) cylinder front support using fifty-four P/N RA011205C104 bolts (3/8-16 x 1-1/4 Lg.) and P/N RA301209C000 spring lockwashers (3/8 dia. bolt). Torque bolts to 190-210 in.-lbs. ______________

1.13 Check for free rotation of the P/N 490657(ND) intermediate housing, with P/N 185201(ND) cylinder front support attached, relative to the P/N 490661(ND) center housing and support assembly. ______________

1.14 Unless otherwise noted lubricate parts at assembly with MIL-L-23699 oil. ______________

1.15 Cover unit with plastic to protect from contamination if waiting for subassemblies for installation in the test rig. ______________

2.0 Intermediate Bearings Sub-Assembly

Rig Parts: (Reference LS34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
45	185181	Support, Intermediate Bearing	1	
73	185190	Bearing (SKF No. 7021 CTC/C78/G5) *	2	
40	185207	Spacer, Center Bearing Inner	1	
82	185199	Shim, Washer	1	
83	185186	Washer, Wave Spring	1	
60	185200	Washer, Cuplock (6.6250-12)	1	
55	185203	Nut, Spanner (6.6250-12)	1	

Note: P/N 185208 Spacer, Center Bearing Outer, Item 41 is not to be used.

* N-D QOL21DTL7A Optional

Check

2.1 Clean all parts thoroughly. ____

2.2 Measure width of P/N 185190 bearings inner races (both bearings), and width of P/N 185207 center bearing inner spacer. ____

2.3 Measure length of 6.3000-6.2990 bore for bearings, spacer and shim washer in P/N 185181 support (B/P is 3.066-3.062). ____

2.4 Measure height of P/N 185186 wave spring washer with a 500 lb. load imposed axially. ____

2.5 Subtract sum of measurements of 2.2 and 2.4 from measurement of 2.3 above ____

2.6 Grind thickness of P/N 185199 shim (B/P .21) to the dimension obtained in 2.5 above. Remove material from the face opposite the counterbore face. ____

2.7 Install first P/N 185190 bearing in the P/N 185181 support with the outer race counterbore inward, the P/N 185207 spacer, the second P/N 185190 bearing with the outer race counterbore facing the first bearing, the P/N 185199 shim washer with the counterbored face contacting the second bearing outer race, the P/N 185186 wave spring washer, the P/N 185200

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cuplock washer, and the P/N 185203 spanner nut. Tighten the spanner nut using P/N CW928609 wrench. Crimp the cuplock washer into the spanner nut scallops at one place. (The fit of the bearings O.D. in the support I.D. is 0.0001L. - 0.0011L.)

2.8 Unless otherwise noted lubricate part at assembly with MIL-L-23699 Oil.

2.9 Cover unit with plastic to protect from contamination if awaiting further rig assembly.

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3.0 Turbine Input Shaft and Bearings Sub-Assembly

<u>Rig Parts:</u> (Reference LS34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
44	185198	Turbine Input Shaft	1	
39	185223	Center Bearing Front Spacer	1	
Para 2.0	-	Intermediate Bearings Sub-Assembly	1	
38	185212	Rear Coupling Spacer	1	
71	185188	Bearing, Roller (SKF)-Inner Race Only	1	
58	185216	Washer, Cuplock	1	
53	185205	Nut, Spanner (3.6250-12)	1	
52	185204	Nut, Spanner (2.9330-12)	2	

<u>Assembly Fixtures:</u>

P/N	Name	Quantity
CW-928615	Support and Alignment Plate-Input Shaft	1
CW-928611	Turbine Input Shaft Dummy Coupling	1

Check

3.1 Clean all parts thoroughly. ______

3.2 Install P/N CW-928615 support and alignment plate on the P/N 185198 turbine input shaft. The fixture pilots on the input shaft journal O.D. (for P/N 185189 ball bearing) with the hub of the fixture toward the input shaft shoulder (Ref. LS34822 sheet 4). ______

3.3 Install the P/N 185204 spanner nut on the input shaft and tighten to retain the P/N CW-928615 fixture (Ref. LS34822 sheet 4). ______

3.4 Position the input shaft, with fixture attached, on the 40 K gearbox assembly table with the input end of the shaft down and the fixture plate resting on the assembly table. Clamp the fixture plate to the assembly table using "C" clamps. ______

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Check

3.5 Install the P/N 185223 center bearing front spacer on the P/N 185198 turbine input shaft with the three .067 diameter jet holes directed away from the shaft shoulder and toward the bearing. ____

3.6 Heat the intermediate bearings and support sub-assembly, as assembled per paragraph 2.0, to 250°F and install on the input shaft and seat on the P/N 185223 spacer (Bearings I.D. to shaft O.D. fit is 0.0005 tight - 0.0014 tight). ____

3.7 Install the P/N 185212 rear coupling spacer with the slinger flange and three .067 diameter oil jet holes directed toward the intermediate bearing. ____

3.8 Install the P/N CW-928611 turbine input shaft dummy coupling with the I.D. counterbored end toward the P/N 185212 coupling. ____

3.9 Install the P/N 185216 cuplock washer with the two tangs engaging the two slots in P/N 185198 shaft, and install the P/N 185205 spanner nut. Tighten the nut snugly using P/N CW-928606 spanner wrench. Do not crimp the cuplock washer. ____

3.10 Heat the P/N 185188 bearing inner race to 250°F and install the inner race onto the P/N 185198 shaft and seat inner race against the shaft shoulder. (Fit is .0001 tight - .0014 tight). ____

3.11 Install the P/N 185204 spanner nut on the P/N 185198 input shaft and tighten the nut to retain the P/N 185188 bearing inner race. ____

3.12 Unless otherwise noted lubricate parts at assembly with MIL-L-23699 oil. ____

3.13 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ____

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4.0 Input shaft and front output shaft sub-assembly

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
A10	490653	Output Shaft Assembly, Front	1	
Para. 3.0	—	Turbine Input Shafts and Bearings Sub-Assembly	1	
--	RA011205P014	Bolt (3/8-16 x 7/8 Lg.)	3	

Assembly Fixture:

--	CW-928616	Positioner - Center Housing and Turbine Input Shaft	1	

Check

4.1 Clean all parts thoroughly ______

4.2 Raise the input shaft and bearings sub-assembly, as assembled in paragraph 3.0, and invert to have the input end up. Use eye bolts thru holes in the P/N 185181 support. ______

4.3 Place the CW-928616 positioner plate on the 40 K gearbox assembly table, centered and clamped to the assembly table using "C" clamps ______

4.4 Lower the input shaft and bearings sub-assembly through the CW-928616 positioner plate and into the 3.8" I.D. tube at the center of the assembly table, and with the P/N 185205 spanner nut resting on the top face of the assembly table tube. ______

4.5 Remove the P/N 185204 spanner nut and P/N CW-928615 support plate from the input end of the P/N 185198 shaft. ______

4.6 Assemble P/N 490653 output shaft assembly on the turbine input shaft and bearings sub-assembly, as assembled per paragraph 3.0. Align holes and attach the P/N 490653 shaft assembly to the P/N 185181 intermediate bearing support using three P/N RA011205P014 bolts. Tighten the three bolts snugly to hold parts in place while handling. (The pilot fit between the output shaft and the bearing support is 0.0005" loose - 0.0025" loose. ______

QCSEE A-3

Check

4.7 Unless otherwise noted lubricate parts at assembly with MIL-L-23699 Oil _____

4.8 Cover unit with plastic to protect from contamination if awaiting further rig assembly. _____

QCSEE A-3

5.0 Input and Front Output Shafts, and Front Housing Sub-Assembly.

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
Para. 4.0	-	Input Shaft and Front Output Shaft sub-assembly	1	
A3	490658(ND)	Front Housing and Flange Assembly	1	
52	185204	Nut, Spanner (2.9330-12)	1	

Assembly Fixtures:

--	CW-928615	Support and Alignment Plate-Input Shaft	1	
--	-	Bolt (5/16-24 x 1"Lg.-Steel Comm.)	4	
--	-	Eyebolt (5/8-11)	1	

Check

5.1 Clean all parts thoroughly.

5.2 Install P/N CW-928615 support and alignment plate on shafts and bearings sub-assembly as assembled in paragraph 4.0. P/N CW-928615 fixture pilots on the input shaft journal O.D. (for P/N 185189 ball bearing) with the hub of the fixture toward the input shaft shoulder

5.3 Install the P/N 185204 spanner nut on the input shaft and tighten to retain the P/N CW-928615 fixture.

5.4 Attach the P/N 490658 front housing and flange assembly to the P/N CW-928615 fixture with the fixture on the front housing vertical centerline (the two holes in the P/N CW-928615 with the closer spacing are to be at the bottom of the P/N 490658 front housing-aligned with the oil drain in the P/N 490658 housing). The P/N CW-928615 fixture is to be attached to the inside face of the P/N 490658 housing flange. Use the four 5/16-24 x 1" Lg. bolts to attach the P/N 490658 housing to the P/N CW-928615 fixture.

5.5 Install the 5/8-11 eyebolt in the input end of the P/N 185198 input shaft.

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5.6 Unless otherwise noted lubricate parts at assembly with MIL-L-23699 Oil ____

5.7 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ____

QC SEE A-3

6.0 Input and Output shafts, Front Housing, and Main Housing Assembly - Sub-Assembly

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
Para. 1.0	-	Main Housing Sub-Assembly	1	
Para. 5.0	-	Input and Front Output Shafts, and Front Housing Sub-Assembly	1	
110	RA011205C108	Bolt (3/8-16 x 1-1/2 Lg)	4	
130	RD751205C000	Nut (3/8-16)	4	

Assembly Fixture:

-	CW-928616	Positioner-Center Housing and Turbine Input Shaft	1	
-	-	Bolt (3/8-16 x 1-1/4 LG.)	4	
-	-	Nut (3/8-16)	4	

Check

6.1 Clean all parts thoroughly. ____

6.2 Lift Sub-Assembly of paragraph 5.0 by the eyebolt at the input end of the P/N 185198 input shaft and lower into the main housing sub-assembly (paragraph 1.0). ____

6.3 Attach the P/N 490658 front housing to the P/N 490657 intermediate housing flange using four P/N RA011205C108 bolts and four P/N RD 751205C000 nuts spaced at approximately 90° intervals. Lockwashers are not required at this stage of assembly. Torque nuts to 190-210 in-lbs. ____

6.4 Install P/N CW 928616 positioner plate over the bottom end of the input shaft and attach the positioner plate to the P/N 490661 (ND) center housing flange bottom face using four 3/8-16 x 1-1/4 Lg. bolts and four 3/8-16 nuts. ____

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		Check
6.5	Invert this complete sub-assembly such that the P/N 490661 center housing is upward.	______
6.6	Unless otherwise noted lubricate parts at assembly with MIL-L-23699 Oil.	______
6.7	Cover unit with plastic to protect from contamination if awaiting further rig assembly.	______

QC SEE A-3

7.0 Brush Block Bracket and Brush Block Assembly

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
64	185192	Slip Ring and Brush Block Assy.	1	
103	RA020805P110	Bolt (1/4-28 x 1-5/8 Lg.)	12	
223	2067D969	Washer, Tablock (1/4 Dia. Bolt)	6	
218	MS-9804-08	Screw (8-32 x 5/8 Lg.)	8	
217	ESNA-1802-82	Nut, Self-Lock (8-32) or SM-1813-82	8	
Para. 6.0	-	Main Housing & Shafts Sub-Assy.	1	
A200	490665	Brush Block Bracket Assembly	2	
112	RA021205P112	Bolt (3/8-24 x 1-3/4 Lg.)	4	
222	2067D970	Tablock Washer (3/8 Dia. Bolt)	2	

Check

7.1 Clean all parts thoroughly.

7.2 Remove the P/N CW-928616 Fixture.

7.3 Install the slip ring assembly (sub-assembly of P/N 185192) on the P/N 185181 bearing support of paragraph 6.0 sub-assembly, and attach the slip ring to the P/N 185181 support using twelve P/N RA020805P110 bolts and six P/N 2067D969 tablock washers. Torque the bolts to 65-70 in-lbs.

7.4 Install the two brush block assemblies (sub-assembly of P/N 185192) on the two P/N 490665 brush block bracket assemblies using the eight P/N MS-9804-08 screws and eight P/N ESNA 1802-82 (or SM-1813-82) nuts. Assemble the nuts loosely to allow movement of the brush blocks on the brush block brackets.

7.5 Install the two P/N 490665 brush block housing bracket assemblies, with brush block assemblies attached, on the upper face of the P/N 490661(ND) center housing and support assembly using four P/N RA021205P112 bolts in two holes at the top and two holes at the bottom, plus two P/N 2067D970 tablock washers. Route the strain gage leads from the brush block assemblies, along the rear face of the brush block brackets to the P/N 490661-4(ND) rear cylinder support, circumferentially around the support from the bottom brush block to join the leads from the top brush block, and out through the P/N 490661-6 (ND) center housing vent boss.

QC SEE A-3

Check

7.5 (Continued)

Note: Dowels in P/N 490661 assembly align the P/N 490665 brackets.

Torque the four P/N RA021205P112 bolts to 215-235 in.-lbs.

Torque the eight P/N ESNA 1802-82 (or SM 1813-82) nuts to 18-20 in.-lbs. after adjusting the brush block contact finger tension.

7.6 Unless otherwise noted lubricate the bolts and nuts at assembly with MIL-L-23699 Oil.

7.7 Cover unit with plastic to protect from contamination if awaiting further rig assembly.

8.0 Shield Assembly, Output Shaft Rear Assembly, Shroud, and Ring Gear

Reduction Gear Hardware: (Reference LS-34810 and Bill of Material No. 210)

Item	P/N	Name	Quantity	Check
1	185139	Ring Gear	1	

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
A8	490664(ND)	Shield Assembly	1	
A11	490654	Output Shaft Assembly, Rear	1	
30	185217	Shroud	1	
114	185224	Bolt (1/2-20 x 6" Lg)	20	
131	185226	Nut (1/2-20)	20	
224	2067D971	Washer, Tablock (1/2 Dia. Bolt)	20	
Para. 7.0	-	Main Housing, Shafts, Slip Ring and Brush Block-Sub-Assembly	1	

Check

8.1 Clean all parts thoroughly

8.2 Tap the P/N 490664(ND) shield assembly into the P/N 490661(ND) center housing assembly and against the output end flange face, with cone of the shield assembly projecting toward the input end and with the offset hole in the P/N 490664 shield assembly aligning with the offset hole in the P/N 490661 housing assembly. (The fit of the shield O.D. into the 28.750" I.D. of the housing is 0.001 loose - 0.001 tight).

8.3 Install the P/N 185139 ring gear on the P/N 490654 rear output shaft assembly with the ring gear up. and the ring gear external splines engaging the output shaft internal splines, and the ring gear stop face bottomed on the output shaft stop face. Route the ring gear strain gage leads from the rim of the ring gear through holes between the gear teeth and spline teeth and along the inside cone face of the output shaft to a junction near the inner end of the inside cone face.

QC SEE A-3

Check

8.4 Install the P/N 185139 ring gear and P/N 490654 output shaft sub-assembly onto the P/N 185181 intermediate bearing support, insuring that the offset holes in the output shaft and the bearing support align (the pilot fit between the output shaft and the bearing support is 0.0005"loose - 0.0025" loose). When installing the P/N 490654 output shaft onto the P/N 185181 bearing support, feed the strain gage leads from the slip ring through the two 0.28" Diameter Holes in the output shaft to connect at the junction of the ring gear strain gage leads. ______

8.5 Install the P/N 185217 shroud onto the P/N 490654 output shaft, aligning the offset holes, and attach the shroud and output shaft to the bearing support using twenty P/N 185224 bolts, twenty P/N 185226 nuts, and twenty P/N 2067D971 tablock washers (ten on each end of the bolts). Reverse the bolts from that shown on LS-34822 such that the nuts are at the output end. Torque the nuts to 2000 - 2100 in.-lbs. After installing two P/N 185224 bolts, P/N 185226 nuts, and P/N 2067D971 tablock washers remove the three P/N RA011205P014 bolts, that were installed for assembly purposes in paragraph 4.6 to hold the P/N 490653 shaft assembly to the P/N 185181 bearing support. ______

8.6 Unless otherwise noted lubricate the parts at assembly with MIL-L-23699 Oil. ______

8.7 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ______

QCSEE A-3

9.0 Star Gear & Support Assembly and Turbine Input Shaft Support Sub-Assembly

Reduction Gear Hardware & Rig Parts: (Reference LS-34822 and Bill of Material No. 212).

Item	P/N	Name	Quantity	Check
QCSEE A-1	-	Star Gear & Support Sub-Assembly	1	
107	RA021 005P100	Bolt (5/16-24 x 1" Lg.)	4	
Para. 8.0	-	Test Rig Sub-Assembly	1	

Assembly Fixture:

Item	P/N	Name	Quantity	Check
-	CW-928617	Support-Turbine Input Shaft	1	

Check

9.1 Clean all parts thoroughly, except where previously cleaned and protected in plastic covers. ______

9.2 Install P/N CW-928617 turbine input shaft support on P/N 185187 pilot ring (detail test rig part of the star gear and support sub-assembly) using the four P/N RA021005P100 bolts. Lockwashers are not required at this stage of assembly. Torque the four bolts to 120-130 in-lbs. ______

9.3 Lower the star gear and support assembly, with the CW-928617 support attached, into the test rig sub-assembly, engaging the gear teeth of the P/N 185157 star gears with the gear teeth of the P/N 185139 ring gear, and continue to lower until the P/N CW-928617 support seats on the rear end face at the P/N 185198 input shaft. ______

Check

9.4 Rotate the star gear and support assembly to position the No. 1 trunnion (See QCSEE A-1 Para. 2.3 for location of trunnion identification numbers) at the top (12 o'clock) position of the test rig, as identified by the offset holes in the support and pilot ring. ____

9.5 Unless otherwise noted lubricate the parts at assembly with MIL-L-23699 Oil. ____

9.6 Cover unit with plastic to protect from contamination if awaiting further rig Assembly. ____

QC SEE A-3

10.0 Rear Output Shaft Shroud, Screen Assembly, and Rear Housing and Flange Assembly

Rig Parts: (Reference LS-34822 and Bill of Material No. 212).

Item	P/N	Name	Quantity	Check
48	185171	Shroud, Output Shaft	1	
115	684-D-107	Bolt, 12 Pt. Hd. (1/4-28 x 3/4 Lg.)	24	
- GE P/N4013101-852602		Screen Assembly	1	
- GE P/N 4013101-907		Support, Screen	1	
- GE P/N J644 P11E		Bolt (1/4-28 x 7/8 Lg.)	24	
- GE P/N J979 P04D		Nut (1/4)	24	
A4	490662(ND)	Rear Housing & Flange Assy.	1	
108	609-D-2	Bolt (5/16-24 x 1-7/8 Lg.)	70	
126	RA301009C000	Washer, Lock, Spring (5/16)	70	
113	RA011205P200	Bolt (3/8-16 x 2" Lg.)	50	
130	RD751205C000	Nut (3/8-16)	54	
127	RA301209C000	Washer, Lock, Spring (3/8)	108	
Para. 9.0	-	Test Rig Subassembly	1	
111	RA011205C112	Bolt (3/8-16 x 1-3/4 Lg.)	4	

		Check
10.1	Clean all parts thoroughly.	
10.2	Install P/N 185171 shroud onto P/N 490654 output shaft using twenty-four P/N 684-D-107 Bolts. Torque bolts to 65-70 in.-lbs.	
10.3	Install the GE P/N 4013101-852602 screen assembly onto the GE P/N 4013101-907 screen support. Use twenty-four GE P/N J644 P11E bolts and twenty-four GE P/N J979P04D nuts to attach the screen to the support. Torque the bolts to 65-70 in.-lbs.	

Check

10.4 Install the screen and support subassembly of paragraph 10.3 above into the P/N 490662(ND) rear housing assembly, aligning the offset holes in the support and in the housing, and tapping the support into the 22.000" I.D. and the screen into the 28.000" I.D. of the P/N 490662(ND) housing (Fit is 0.001" loose - 0.001" tight at both diameters). ____

10.5 Install the P/N 490662 (ND) rear housing, with the screen and support attached, onto the P/N 185187 (ND) pilot ring, aligning the offset holes in the housing and pilot ring, and into the P/N 490664 shield assembly and against the rear end flange face, and aligning the offset holes in the housing and the shield (The fit of the housing pilot O.D. into the 28.375" I.D. of the shield is 0.001" loose-0.001" tight). Use seventy P/N 609-D-2 bolts and seventy P/N RA301009C000 spring lockwashers to attach the P/N 490662 (ND) rear housing, with the screen and support, to the P/N 185187 (ND) pilot ring and the star gear support. Torque the bolts to 170-190 in.-lbs. Use fifty P/N RA011205P200 bolts, four P/N RA011205C112 bolts, fifty-four P/N RD751205C000 nuts, and one hundred-eight P/N RA301209C000 spring lock washers to attach the P/N 490662 (ND) rear housing to the P/N 490664 shroud and P/N 490661 (ND) center housing. Torque the nuts to 190-210 in.-lbs. The four P/N RA011205C112 bolts are used at the bottom four holes with the bolts reversed such that the nuts are toward the rear as shown in section H-H of LS-34822. ____

10.6 Unless otherwise noted lubricate the parts at assembly with MIL-L-23699 Oil. ____

10.7 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ____

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11.0 Sun Gear Assembly

Rig Parts: (Reference LS-34822 and Bill of Material No. 212, LS-34810 and Bill of Material No. 210, and QCSEE A-2)

Item	P/N	Name	Quantity	Check
QCSEE A-2	-	UTW Sun Gear Subassembly	1	
Para. 10.0	-	Test Rig Subassembly	1	

Assembly Fixture:

-	CW-928620	Immobilizer-Test Rig Input Shaft	1	
-	CW-928606	Spanner Wrench	1	Check

11.1 Clean all parts thoroughly

11.2 Remove the four P/N RA021005P100 bolts and the P/N CW-928617 turbine input shaft support from P/N 185187 pilot ring, rear. _____

11.3 Remove the P/N 185205 spanner nut using P/N CW-928606 spanner wrench and the P/N CW-928620 immobilizer on the input end of the input shaft if necessary. Remove the P/N 185216 cuplock washer and P/N CW-928611 turbine input shaft dummy coupling. _____

11.4 Install the sun gear subassembly, from QCSEE A-2, on the input shaft rear end, engaging the sun gear teeth and the star gear teeth and seating the P/N 185174 coupling against the P/N 185212 rear coupling spacer. _____

11.5 Install the P/N 185216 cuplock washer with the two tangs engaging the two slots in P/N 185198 shaft. Install the P/N 185205 spanner nut and tighten using P/N CW-928606 spanner wrench and P/N CW-928620 immobilizer on the input end of P/N 185198 shaft. Engage the key of the immobilizer in the key slot of the shaft, and use a bar through the 7/8" hole to immobilize the shaft when tightening the spanner nut. Crimp the cuplock washer into one scallop of the spanner nut. _____

QC SEE A-3

Check

11.6 Loosen the P/N 185204 spanner nut that is retaining the P/N CW-928615 support and alignment plate at the input end of the P/N 185198 shaft, and using the P/N CW-928606 spanner wrench and immobilizing the P/N 185173 (ND) output front shaft, check for backlash in the rear gearing. Retighten P/N 185204 spanner nut. ______

11.7 Unless otherwise noted lubricate the parts at assembly with MIL-L-23699 Oil. ______

11.8 Cover unit with plastic to protect from contamination if awaiting further rig assembly.

12.0 Rear End Housing and Flange Assembly, End Housing Bearing Support, and Input Shaft Rear Bearing

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
A5	490655 (ND)	End Housing and Flange Assy.	1	
47	185177	End Housing Bearing Support	1	
71	185188	Roller Bearing (SKF-Outer Race, Rollers and Cage Assy.	1	
59	185218	Washer, Cuplock (5.2093-12)	1	
54	185178	Nut, Spanner (5.2093-12)	1	
105	RA021005P010	Bolt (5/16-24 x 5/8 Lg.)	12	
63	2067D966	Washer, Tablock (5/16 Dia. Bolt)	6	
107	RA021005P100	Bolt (5/16-24 x 1" Lg.)	30	
126	RA301009C000	Washer, Spring Lock (5/16)	30	
66	185194	O-Ring (1.171 I.D. x .116 CS)	2	
79	RD593209P000	Union, Hydr. (37°Flare, Tube O.D. 3/8)	2	
65	185193	O-Ring (.468 I.D. x .078 CS)	1	
78	RD591209P000	Union, Hydr. (37° Flare, Tube O.D. 3/8)	1	
67	MS-9386-127	O-Ring (1.424 I.D. x .103 CS)	1	
77	MS20760-20	Adapter, Straight	1	
102	RA020805C012	Bolt (1/4-28 x 3/4 Lg.)	4	
125	RA300809C000	Washer, Spring Lock (1/4)	6	
23	185214	Connector	1	
62	185206	Gasket, Connector	1	
101	RA020805C010	Bolt (1/4-28 x 5/8 Lg.)	2	
Para 11.0	-	Test Rig Subassembly	1	
57	185215	Washer, Cuplock (2.9330-12)	1	
52	185204	Nut, Spanner (2.9330-12)	1	
SK-6675	490667	Connector Assembly, Engine Oil Flow Simulation Orifice	1	
SK-6675	561D14	O-Ring	1	

-1-

Item	P/N	Name	Qty.	Check
-	4013179-783G01	Oil Sump (G.E. Supplied)	1	
95	185231	Gasket-Rear Housing Adapter	1	
100	RA020805P008	Bolt (1/4-28 x 1/2 Lg)	22	
125	RA300809C000	Washer, Lock, Spring (1/4)	22	

Reduction Gear Hardware (Reference LS 34810 and Bill of Material No. 210).

Item	P/N	Name	Qty.	Check
A4	490639	Oil Supply Tube	1	
11	MS-9388-022	O-Ring	3	

Assembly Fixtures:

Item	P/N	Name	Qty.	Check
-	CW-928607	Wrench-Spanner Nut	1	
-	CW-928620	Input Shaft Immobilizer	1	
-	CW-928608	Wrench-Spanner Nut	1	
-	CW-928618	Support-Turbine Input Shaft at Cover	1	
-	-	Bolt (5/16-24 x 1-1/8 Lg. Comm. Steel)	6	

12.1 Clean all parts thoroughly

12.2 Lubricate the P/N 185177 Bearing Support O.D. with Lubriplate and press the support into the P/N 490655 (ND) end housing assembly, insuring that the attaching holes in the flange of the support align with those in the end housing and seating the support flange against the end housing face (the support fit in the end housing is 0.001 loose - 0.001 tight).

12.3 Install the twelve P/N RA021005-P010 bolts and six P/N 2067D968 tablock washers to attach the bearing support to the end housing. Torque the bolts to 120-130 in.-lbs.

12.4 Lubricate the P/N 185188 bearing outer race O.D. with Lubriplate and press the bearing outer race with roller and cage assembly into the P/N 185177 bearing support, seating the outer race against the support flange. (the bearing outer race fit in the support is 0.0004 loose - 0.0011 tight).

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12.11 Install the P/N 185193 O-Ring on the P/N RD591209P000 union, lubricating the O-Ring with Lubriplate, and install the union into the P/N 490665(ND) end housing. ________

12.12 Lubricate the P/N MS-9388-127 O-Ring with Lubriplate and install in the groove in the flange face of P/N 490655-4(ND) adapter extension (part of P/N 490655 end housing and flange Assembly). Install the P/N MS-20760-20 straight adapter on the adapter extension using four RA020805C012 bolts and four P/N RA300809C000 spring lock washers. Torque the bolts to 65-70 in.-lbs. ________

12.13 Install the P/N 185214 connector on the P/N 185187 pilot ring using one P/N 185206 gasket, two P/N RA020805C010 bolts, and two P/N RA300809C000 spring lock washers. Torque the bolts to 65-70 in.-lbs. ________

12.14 Install the P/N 490667 connector assembly, with P/N 561D14 O-Ring, into the P/N 490662(ND) rear housing (Reference SK-6675). Lubricate the O-Ring with Lubriplate prior to installation. ________

12.15 Install the P/N RD593209P000 hydraulic union, with P/N 185194 O-Ring, into the P/N 490661(ND) center housing. Lubricate the O-Ring with Lubriplate prior to installation. ________

12.16 Install the P/N CK-928618 support on the P/N 490655 end housing using six 5/16-24 x 1-1/8 Lg. commercial steel bolts. Torque the bolts to 120-130 in.-lbs. ________

12.17 Install the P/N 4013179-783G01 oil sump (G.E. supplied) with P/N 185231 gasket on the P/N 490655(ND) rear end housing using twenty-two P/N RA020805P008 bolts and twenty-two P/N RA300809C000 spring lock washers. Torque the bolts to 65-70 in.-lbs. ________

12.18 Unless otherwise specified lubricate all parts with MIL-L-23699 Oil. ________

12.19 Cover all external openings with plastic caps/cardboard/tape as applicable. ________

Check

12.20 Invert the test rig subassembly to have the input end of the P/N 185198 input shaft up. ________

12.21 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ________

QCSEE A-3

13.0 Ring Gear, Star Gear and Support Subassembly, and Front OUtput Shaft Shroud

Reduction Gear Hardware and Rig Parts (Reference LS34810 and Bill of Material NO. 210).

Item	P/N	Name	Quantity	Check
1	185139	Ring Gear	1	
QCSEE A-1	-	Star Gear & Support Subassembly	1	

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
48	185171	Shroud, Output Shaft	1	
115	684D107	Bolt, 12 Pt. Hd. (1/4-28 x 3/4 Lg)	24	
Para 12.0	-	Test Rig Subassembly	1	

Assembly Fixtures:

Item	P/N	Name	Quantity	Check
-	CW-928617	Support-Turbine Input Shaft	1	
107	RA021005P100	Bolt (5/16-24 x 1" Lg.)	4	

13.1 Clean all parts thoroughly.

13.2 Remove the four P/N RA011205C108 bolts and four RD751205C000 nuts attaching the front housing to the intermediate housing. Remove the four 5/16-24 x 1" Lg. bolts attaching the support and alignment plate to the front housing. Remove the P/N 490658 front housing assembly.

13.3 Remove the P/N 185204 spanner nut.

13.4 Remove the P/N CW-928615 support and alignment plate from the input shaft.

Check

13.5 Install the P/N 185139 ring gear on the P/N 490653 front output shaft assembly with the ring gear up, and the ring gear external splines engaging the output shaft internal splines, and the ring gear stop face bottomed on the output shaft stop face. ____

13.6 Install P/N CW-928617 turbine input shaft support on P/N 185187 pilot ring (detail test rig part of the star gear and support subassembly) using the four P/N RA021005P100 bolts. Lockwashers are not required at this stage of assembly. Torque the four bolts to 120-130 in-lbs. ____

13.7 Lower the star gear and support assembly, with the CW-928617 support attached, into the test rig subassembly, engaging the gear teeth of the P/N 185157 star gears with the gear teeth of the P/N 185139 ring gear, and continue to lower until the P/N CW-928617 support seats on the shoulder face of the P/N 185198 input shaft. ____

13.8 Rotate the star gear and support assembly to position the No. 1 trunnion (See QCSEE A-1 Para. 2.3 for location of trunnion identification numbers) at the top (12 o'clock) position of the test rig, as identified by the offset holes in the support and pilot ring. ____

13.9 Install P/N 185171 shroud onto P/N 490653 output shaft using twenty-four P/N 684D107 bolts. Torque the bolts to 65-70 in.-lbs. ____

13.10 Unless otherwise noted lubricate the parts with MIL-L-23699 Oil. ____

13.11 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ____

QC SEE A-3

14.0 Front Housing and Flange Assembly

Rig Parts: (Reference LS-34822 and Bill of Material No.212).

Item	P/N	Name	Quantity	Check
A-3	490658(ND)	Front Housing & Flange Assy.	1	
108	609D2	Bolt (5/16-24 x 1-7/8 Lg.)	70	
126	RA301009C000	Washer, Lock, Spring (5/16)	70	
110	RA011205C108	Bolt (3/8-16 x 1-1/2 Lg.)	54	
130	RD751205C000	Nut (3/8-16)	54	
127	RA301209C000	Washer, Lock, Spring (3/8)	108	
Para 13.0	-	Test Rig Subassembly	1	

14.1 Clean all parts thoroughly.

14.2 Install the P/N 490658 front housing onto the P/N 185187 pilot ring and the P/N 490657 intermediate housing, aligning the offset holes of the P/N 490658 housing with those of the P/N 185187 pilot ring and the P/N 490657 housing. Use the seventy P/N 609D2 bolts and seventy P/N RA301009C000 springlock washers to attach the P/N 490658 front housing to the P/N 185187 pilot ring and the star gear support. Torque the bolts to 170-190 in.-lbs. Use fifty-four P/N RA011205C108 bolts, fifty-four P/N RD751205C000 nuts, and one-hundred-eight P/N RA301309C000 spring lock washers to attach the P/N 490658 front housing to the P/N 490657 intermediate housing. Four of the P/N RA011205C108 bolts at the bottom centerline are to be assembled reversed as shown on LS-34822, Sheet 1 and Section H-H reference. Torque the nuts to 190-210 in.-lbs.

14.3 Remove the four P/N RA021005P100 bolts and the P/N CW-928617 turbine input shaft support.

14.4 Unless otherwise noted lubricate the parts at assembly with MIL-L-23699 Oil.

14.5 Cover unit with plastic to protect from contamination if awaiting further rig assembly.

QCSEE A-3

15.0 Sun Gear Assembly

Reduction Gear Hardware & Rig Parts: (Reference LS-34822 and Bill of Material No. 212).

Item	P/N	Name	Quantity	Check
QCSEE A-2	-	UTW Sun Gear Subassembly	1	
Para 14.0	-	Test Rig Subassembly	1	
94	185219	Spacer - Coupling	1	
58	185216	Washer, Cuplock (3.6250-12)	1	
53	184205	Nut, Spanner (3.6250-12)	1	
202	185226 Ortman-Miller Model GH	Cylinder, Oil (3" Bore, 1500 psi)		
203	185228 Ortman-Miller	Clevis - Rod (3" Bore)	1	
204	185227	Plate-Eye	1	
205	Ortman-Miller 525.60-2	Pin, Straight (3/4 O.D. x 2.734 Lg) & 2 Ret. Rings	1	
206	Ortman-Miller 525.61-2	Pin, Straight (7/8 O.D. x 2.436 Lg.) & 2 Ret. Rings	1	
211	MS-51975-32	Screw, Shoulder (1/2 Dia. shoulder 3/8-16 x 1.75 LG.)	2	
212	MacLean-Fogg 22 SFU 3816	Nut, small flange (3/8-16) Uni-Torque Lock	2	

Assembly Fixture:

Item	P/N	Name	Quantity	Check
-	CW-928620	Immobilizer-Test Rig Input Shaft	1	
	CW-928606	Spanner Wrench	1	

		Check
15.1	Clean all parts thoroughly	____

QCSEE A-3

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15.2 Install the P/N 185227 eye plate on the P/N 490661(ND) center housing and support assembly using two P/N MS-51975-32 shoulder screws and two P/N 22 SFU 3816 nuts. Torque the nuts to 190-210 in.-lbs. ____

15.3 Install the P/N 185228 cylinder to the P/N 185227 eye plate using the P/N 525.60-2 straight pin with retaining rings on each end. ____

15.4 Install the P/N 185228 Clevis Rod to the P/N 185201(ND) front cylinder support using the P/N 525.61-2 straight pin with retaining rings on each end. ____

15.5 Using shop air pressure retract the P/N 185228 hydraulic cylinder to the full retract position. ____

15.6 Install the P/N 185219 coupling spacer on the P/N 185198 input shaft with the 0.045 dia. oil jet hole directed forward toward the sun gear assembly. ____

15.7 Using the P/N CW-928620 Immobilizer on the input end of the input shaft, rotate the input shaft CCW (as viewed from the input end), and at the same time rotate the star gear CCW (as viewed from the input end), with access through the oil drain hole at the bottom of the P/N 490658(ND) front housing, to take out the backlash in the front and rear gearing. ____

15.8 Install the sun gear subassembly, from QCSEE A-2, on the input shaft front end, engaging first the P/N 185174 coupling to P/N 185198 input shaft spline teeth, and then the sun gear to star gear teeth, and seating the P/N 185174 coupling against the P/N 185219 coupling spacer. It may be necessary to re-position the coupling splines on the shaft splines a number of times to find the position where the sun gear and star gears will engage fully and easily. The direction of re-indexing of the splines will depend upon the direction of mis-match of the gear teeth. If unable to engage the gear teeth, energize the hydraulic cylinder using shop air pressure and extend the cylinder in increments to a maximum of 1" from full retract. Repeat the above procedure to engage the gear teeth. ____

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Check

15.9 Install the P/N 185216 cuplock washer and P/N 185205 spanner nut on the input shaft front end. Tighten the spanner nut using P/N CW-928606 spanner wrench and P/N CW-928620 immobilizer on the input end of the input shaft. Crimp the cuplock washer into one scallop of the spanner nut. ____

15.10 Unless otherwise noted lubricate the parts at assembly with MIL-L-23699 Oil. ____

15.11 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ____

QCSEE A-3

16.0 Front End Housing and Flange Assembly, End Housing Bearing Support, Input Shaft Front Bearing, Front Housing and Nozzle Assembly, Front Housing and Seal Assembly, and Rear Cover and Nozzle Assembly.

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Quantity	Check
A5	490655(ND)	End Housing & Flange Assy.	1	
47	185177	End Housing Bearing Support	1	
72	185189	Bearing, Ball, Radial (SKF 6215)	1	
59	185218	Washer, Cuplock (5.2093-12)	1	
54	185178	Nut, Spanner (5.2093-12)	1	
105	RA021005P010	Bolt (5/16-24 x 5/8 Lg.)	12	
63	2067D968	Washer, Tablock (5/16 Dia. bolt)	6	
107	RA021005P100	Bolt (5/16-24 x 1" Lg.)	30	
126	RA301009C000	Washer, spring Lock (5/16)	30	
66	185194	O-Ring (1.171 I.D. x .116 CS)	1	
79	RD593209P000	Union, Hydr. (37° Flare, Tube O.D. 3/8)	1	
65	185193	O-Ring (.468 I.D. x .078 CS)	1	
78	RD591209P000	Union, Hydr. (37° Flare, Tube O.D. 3/8)	1	
67	MS-9388-127	O-Ring (1.424 I.D. x .103 CS)	1	
77	MS-20760-20	Adapter, Straight	1	
102	RA020805C012	Bolt (1/4-28 x 3/4 Lg.)	4	
125	RA300809C000	Washer, Spring Lock (1/4)	6	
23	185214	Connector	1	
62	185206	Gasket, Connector	1	
101	RA020805C010	Bolt (1/4-28 x 5/8 Lg.)	2	
57	185215	Washer, Cuplock (2.9330-12)	1	
52	185204	Nut, Spanner (2.9330-12)	1	
A9	490652	Front Housing & Nozzle Assy.	1	
68	MS-9388-250	O-Ring (4.984 I.D. x .139 CS)	2	
69	MS-9388-251	O-Ring (5.109 I.D. x .139 CS)	2	
A400	490666	Housing & Seal Assy.-Front	1	
106	RA021005C014	Bolt (5/16-24 x 7/8 Lg.)	12	
126	RA301009C000	Washer, Lock, Spr. (5/16)	12	
36	185221	Ring, Retaining, Oil	1	
80	185220	Ring, Retaining (Spirolox RR-125)	1	

Item	P/N	Name	Qty.	Check
A6	490651	Cover & Nozzle Assy.-Rear	1	
37	185222	Adapter, Oil Transfer	1	
100	RA020805P008	Bolt (1/4-28 x 1/2 Lg.)	2	
123	2067D960	Washer, Tablock (1/4)	2	
Para. 15.0	-	Test Rig Subassembly	1	
31	185210	Adapter, Oil Drain	1	
61	185211	Gasket, Front Housing Adapter	1	
104	RA020805C112	Bolt (1/4-28 x 1-3/4 Lg.)	12	
125	RA300809C000	Washer, Spring Lock (1/4)	12	

__Reduction Gear Hardware__ (Reference LS-34810 and Bill of Material No. 210).

Item	P/N	Name	Qty.	Check
A4	490639	Oil Supply Tube	1	
11	MS-9388-022	O-Ring	3	

__Assembly Fixtures:__

Item	P/N	Name	Qty.	Check
-	CW-928614	Wrench-Spanner Nut	1	
-	CW-928608	Wrench-Spanner Nut	1	
-	CW-928607	Wrench-Spanner Nut	1	

16.1 Clean all parts thoroughly ________

16.2 Lubricate the P/N 185177 bearing support O.D. with Lubriplate and press the support into the P/N 490655 (ND) end housing assembly, insuring that the attaching holes in the flange of the support align with those in the end housing, and seating the support flange against the end housing face (The support fit in the end housing is 0.001 loose - 0.001 tight). ________

16.3 Install the twelve P/N RA021005P010 bolts and six P/N 2067D968 tablock washers to attach the bearing support to the end housing. Torque the bolts to 120-130 in.-lbs. ________

16.4 Lubricate the P/N 185189 bearing outer race O.D. with Lubriplate and press the bearing into the P/N 185177 bearing support, seating the outer race against the support flange. (The bearing outer race fit in the support is 0.0000 - 0.0011 tight). ________

16.4.a Install three P/N MS-9388-022 O-Rings on P/N 490639 oil supply tube, lubricating O-Rings with Lubriplate. Insert the flanged end of the tube into opening in oil manifold attached to star gear support. Do not use 764D107 bolts and 2067D960 tablocks as shown on drawing LS-34810. Tube is to be free and is retained by modified P/N MS-20760-20 adapter (see 16.16).

Check

16.5 Install the end housing and bearing sub-assembly of paragraph 16.4 onto the P/N 185187 pilot ring in the test rig sub-assembly of paragraph 15.0, engaging the bearing inner race I.D. with the input shaft bearing journal O.D. (The bearing inner race fit on the input shaft is 0.0006 loose - 0.0002 tight), inserting the P/N 490639 oil supply tube through the P/N 490655-4 (ND) adapter extension (part of P/N 490655 end housing and flange assembly), and aligning the offset hole of the P/N 490655 (ND) end housing with the offset hole of the P/N 185187 (ND) pilot ring (The fit of the P/N 490655 (ND) end housing O.D. to the P/N 185187 (ND) pilot ring I.D. is 0.001" loose - 0.001" tight).

<u>NOTE</u>: Insure that no bending strain is exerted on the P/N 490639 oil supply tube when installing and aligning the P/N 490655 end housing assembly. ________

16.6 Install the thirty P/N RA021005P100 bolts and thirty P/N RA301009C000 spring lock washers to attach the end housing to the pilot ring. Torque the bolts to 120-130 in.-lbs. ________

16.7 Install the P/N 185215 cuplock washer and P/N 185204 spanner nut on the input shaft to retain the P/N 185189 bearing inner race. Snug the nut using P/N CW-928614 spanner wrench sufficiently to fully seat the P/N 185189 bearing inner race against the shoulder of the input shaft. Remove the six 5/16-24 x 1-1/8 Lg. bolts and the P/N CW-928618 support from the P/N 490655(ND)rear end housing. Using the P/N CW-928607 spanner wrench to immobilize the input shaft at the P/N 185204 spanner nut at the rear end of the input shaft, tighten the P/N 185204 spanner nut at the front end of the input shaft using P/N CW-928614 spanner wrench. Crimp the P/N 185215 cuplock washer into one scallop of the P/N 185204 spanner nut. ________

16.8 Install the P/N 185218 cuplock washer and P/N 185178 spanner nut on the P/N 185177 support to retain the P/N 185189 bearing outer race. Tighten the nut using P/N CW-928608 spanner wrench. Crimp the P/N 185218 cuplock washer into one scallop of the P/N 185178 spanner nut. ________

C3

Check

16.9 Lubricate the P/N MS-9388-251 and MS-9388-250 O-rings with Lubriplate and install in the two grooves of P/N 490652 oil transfer housing assembly; the MS-9388-251 O-ring in the larger O.D. (front) groove, and the MS-9388-250 O-ring in the smaller O.D. (rear) groove. Install the P/N 490652 housing assembly, with O-rings, into the P/N 490655 (ND) front end housing assy., indexing such that the P/N 490652-1(ND) nozzles are at the top and the bottom. __________

16.10 Install the P/N 490666 front main bearing oil seal and retainer assy. into the P/N 490652 oil transfer housing (the fit of the oil seal retainer O.D. to the oil transfer housing I.D. is 0.001" loose - 0.003" loose), and attach the oil seal and retainer assembly and the oil transfer housing assembly to the P/N 490655(ND) front end housing assembly using six P/N RA021005C014 bolts and six P/N RA301009C000 springlock washers. Torque the bolts to 120-130 in.-lbs. __________

16.11 Install the P/N 185221 oil retaining ring and the P/N 185220 Spirolox retaining ring into the P/N 185198 input shaft rear end I.D. __________

16.12 Assemble the P/N 185222 oil transfer adapter onto the P/N 490651 cover and nozzle assembly using two P/N RA020805P008 bolts and two P/N 2067D960 tablock washers. Torque the bolts to 65-70 in.-lbs. __________

16.13 Lubricate the P/N MS-9388-251 and MS-9388-250 O-rings with Lubriplate and install in the grooves of P/N 490651 cover and nozzle assembly; the MS-9388-251 O-ring in the larger O.D. (rear) groove, and the MS-9388-250 O-ring in the smaller O.D. (front) groove. Install the P/N 490651 cover assembly, with O-rings and oil transfer adapter, into the P/N 490655(ND) rear end housing assembly, indexing such that the P/N 490651-1 (ND) nozzles are at the top and the bottom. Attach the P/N 490651 cover assy. to the P/N 490655 (ND) rear end housing using six P/N RA021005C014 bolts and six P/N RA301009C000 springlock washers. Torque the bolts to 120-130 in.-lbs. __________

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16.14 Install the P/N 185194 O-Ring on the P/N RD593209P000 union, lubricating the O-Ring with Lubriplate, and install the union into the P/N 490665(ND) front end housing. ________

16.15 Install the P/N 185193 O-ring on the P/N RD591209P000 union, lubricating the O-ring with Lubriplate, and install the union into the P/N 490665(ND) front end housing. ________

16.16 Lubricate the P/N MS-9388-127 O-ring with Lubriplate and install in the groove in the flange face of P/N 490655-4(ND) adapter extension (part of P/N 490655 front end housing and flange assy.). Install the P/N MS-20760-20 straight adapter on the adapter extension using four P/N RA020805C012 bolts and four P/N RA300809C000 springlock washers. Torque the bolts to 65-70 in.-lbs. ________

16.17 Install the P/N 185214 connector on the P/N 185187 pilot ring using one P/N 185206 gasket, two P/N RA020805C010 bolts, and two P/N RA300809C000 springlock washers. Torque the bolts to 65-70 in.-lbs. ________

16.18 Install the P/N 185210 oil drain adapter with P/N 185211 gasket on the P/N 490655(ND) front end housing using twelve P/N RA020805C112 bolts and twelve P/N RA300809C000 springlock washers. Torque the bolts to 65-70 in.-lbs. ________

16.19 Unless otherwise specified lubricate all parts at assembly with MIL-L-23699 Oil. ________

16.20 Cover all external openings with plastic caps/cardboard/tape as applicable. ________

16.21 Cover unit with plastic to protect from contamination if awaiting further rig assembly. ________

17.0 Hydraulic Loading Cylinders and Input Shaft Drive Coupling

Rig Parts: (Reference LS-34822 and Bill of Material No. 212)

Item	P/N	Name	Qty.	Check
Para 16.0	-	Test Rig Sub-assembly	1	
202	185226 Ortman-Miller Model GH	Cylinder, Oil (3" bore, 1500 psi)	5	
203	185228 Ortman-Miller	Clevis-Rod (3" bore)		
204	185227	Plate-Eye	5	
205	Ortman-Miller 525.60-2	Pin, Straight (3/4 O.D. x 2.734 Lg.) & 2 Ret. Rings	5	
206	Ortman-Miller 525.61-2	Pin, Straight (7/8 O.D. x 2.438 Lg.) & 2 Ret. Rings	5	
211	MS51975-32	Screw, Shoulder (1/2 dia. Shoulder 3/8-16 x 1.75 Lg.)	10	
212	MacLean-Fogg 22 SFC 3816	Nut, Sm. Flange (3/8-16) Uni-Torque Lock	10	
85	MS20066-380	Key, Sq. (3/8 x 3/8 x 1-3/4 Lg.)	1	
88	Waldron-Flex-align Size 1-1/2 HSW	Coupling, Input Shaft Drive	1	

17.1 Clean all parts thoroughly. ________

17.2 Rotate the rig subassembly to the horizontal position with the base on the floor. Remove the two P/N 928619-1 support legs (tubular-30") and the two P/N 928619-4 support legs (tubular 33-7/8"). ________

17.3 Install five P/N 185227 eyeplates on the P/N 490661(ND) center housing and support assembly using ten P/N MS51975-32 shoulder screws and ten P/N 22SFU3816 nuts. Torque the nuts to 190-210 in.-lbs. ________

17.4 Install the five P/N 185228 cylinders to the P/N 185227 eyeplates using the P/N 525.60-2 straight pin with retaining rings on each end. ________

17.5 Install the five P/N 185226 Clevis Rods to the P/N 185201(ND) front cylinder support using the P/N 525.61-2 straight pin with retaining rings on each end.

NOTE: One cylinder assembly was installed in para. 15.0

NOTE: Install the cylinder assemblies with the inlet (extend and retract) fittings positioned radially outward.

17.6 Install the P/N MS-20066-380 key in the key slot of the input shaft front end. Install the Waldron Flexalign coupling external flanged member, P/N 61660-1, over the input shaft with the coupling flange forward. Install the coupling internal member, P/N CO-61660-1, onto the input shaft and engaging the P/N MS-20066-380 Key (The fit of the P/N CO-61660-1 internal coupling member on the input shaft is 0.0005" tight - 0.0010 tight).

17.7 Lift the rig assembly and remove the two P/N 928619-7 support legs (channel).

17.8 Unless other wise noted lubricate parts at assembly with MIL-L-23699 Oil.

17.9 Cover unit with plastic to protect from contamination.

APPENDIX D

UTW LOG SHEETS

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CURTISS-WRIGHT CORPORATION

WRIGHT AERONAUTICAL DIVISION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 11-20-75 STAND NO. 4/178 ENGINE MODEL QCSEE NO. ~~STW~~ SHEET NO. 2

TEST OBJECTIVE

DEI QCSEE - B BUILD NO. 2

PROJECT NO. 66B4.4

Reduction Gear Back to Back, Run in and Step Load

Type of Test: Run in & Step Load

Oil Type Mil-L-23699

Equations:

Input Power -

Electrical $P_E = \frac{V \times A}{746}$ HP

Torquemeter $P_T = \frac{T \times N}{63{,}025}$

Gear Simulated Power - H.P. = $\frac{\text{Load Press} \times R_{ig} \times RPM}{253.23}$

Time	Start / Stop	Dyn RPM	Dyn HP	Total Amps	Volts	Oil GPM	Torq Ind.	Torq Equiv H.P.	Load PSI	H.P.
1150	AM Start	Static Reading								
1205	PM	300	265	40	180	521			21	76.59
1210	Stop 0:55									
1450	PM Start 0:55									
1455		332	1206	90	140	119.6	400	34	21	92.19
1510		378	1249	120	110	1300	130	[illegible]	21	107.1
1520		448	2071	120	130	1505	1940	21.45	21	124.8
1535		510	2627	140	140	1695	1900	25.5	22	142.5
1545		572	2831	150	140	1940	1870	22.95	22	165.8
1555	1:20	590	3430	160	140	1946	2260	[illegible]	106	[illegible]
1610		[illegible]	[illegible]	450	215	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1625		1450	[illegible]	650	215	[illegible]	[illegible]	[illegible]	106	[illegible]
1640		[illegible]	[illegible]	700	215	[illegible]	[illegible]	[illegible]	106	[illegible]
1655	2:50	[illegible]	[illegible]	725	219	[illegible]	[illegible]	[illegible]	106	[illegible]
1715	2:50	178	[illegible]	750	219	[illegible]	[illegible]	[illegible]	106	[illegible]
1810	PM Stop 3:25									

Time	Oil Pressures 1	2	3	4	5	6
1150	46	27	37	49	48.5	
1205	47	27	37	49	48.5	50
1210	Lunch Period – Repair Oil Leak on Sump					
1455	46	27	36	48	47	5.5
1510	46	27	36	48	48	6.0
1520	46	27	36	48	48	9.0
1535	46	27	36	48	48	10.0
1545	46	27	36	48	48	11.0
1555	46	27	36	48	48	12.0
1610	46	27	36	48	46	22.8
1625	46	27	36	48	48	23.0
1640	46	27	36	48	48	25.5
1655	46	27	36	48	48	26.0
1715	46	27	36	48	48	30.0
1810	Dyn Exceeded Max Amp – Removed Unit to Assembly					

T/C Thermocouples °F

Time	Oil In 1	2	3	4	5	Oil Out 6	7	8	9	10	11	Dyno 12	13	14	15	16	17	18	19
1150	181	183	178	181	178	183	183	87	182	106	164	64							
1205	181	183	178	181	178	184	184	187	182	181	167	76	74	75	76	82	80	78	85
1455	180	182	166	180	176	183	182	165	181	178	154	78	80	80	79	83	85	72	87
1510	181	184	167	181	178	184	186	164	182	180	162	79	81	82	80	87	84	74	91
1520	181	184	167	181	178	185	187	160	182	180	164	79	83	83	80	88	84	75	93
1535	181	184	166	181	178	186	188	157	182	182	165	79	84	84	81	89	85	76	96
1545	182	187	167	181	177	186	190	154	183	183	165	80	85	86	82	90	86	77	97
1555	181	184	164	181	177	187	191	152	182	184	166	82	88	90	84	94	89	79	98
1610	188	188	166	192	183	200	202	130	185	200	186	96	110	100	114	113	97	114	120
1625	181	183	158	180	176	200	233	112	182	205	189	90	99	102	92	110	110	93	110
1640	180	183	159	180	176	200	235	108	181	207	191	93	104	106	95	114	116	99	114
1655	181	183	159	182	177	202	237	106	181	209	194	96	108	110	98	117	118	101	117
1715	182	184	158	182	177	210	257	104	182	220	209	103	117	117	102	121	124	108	122

Potter Meters

Time	1	1 cps	2	2 cps	3	3 cps	4	4 cps	5	5 cps	Mils Vibration 1	2	
1150	1214	11500	362	2810	1029	4800	311	11400	172	335			
1205	1211	11500	362	2810	1028	4800	309	11400	169	335	.37	0	
1455	1211	11500	361	2810	1027	4800	310	11400	153	310	.42	0	
1510	1213	11500	366	2810	1027	4800	310	11400	157	310	.4	0	
1520	1214	11500	362	2810	1026	4800	311	11400	169	321	.46	0	
1535	1212	11500	362	2810	1027	4800	311	11400	170	321	.56	0	
1545	1213	11500	363	2810	1027	4800	310	11400	168	320	.5	0	
1555	1211	11500	361	2810	1025	4800	310	11400	163	318	.52	0	
1610	1210	11500	361	2810	1027	4800	310	11400	162	318	1.2	0	I.C. [illegible]
1625	1206	11500	362	2810	1025	4800	310	11400	162	314	1.3	0	
1640	1206	11400	362	2810	1027	4800	310	11400	164	316	1.7	0	
1655	1206	11400	362	2810	1025	4800	310	11400	161	318	1.8	0	
1715	1208	11400	362	2810	1026	4800	310	11400	162	318	1.6	0	

TESTER Durant

OBSERVER Farrell

Misel

CURTISS-WRIGHT CORPORATION

POWER SYSTEMS LOG

DATE 11-20-75 STAND NO. 4/178 ENGINE MODEL QCSEE NO. 4TW SHEET NO. 3

TEST OBJECTIVE

DEI QCSEE - B BUILD NO. 2

PROJECT NO. 66B414

Reduction Gear Back to Back; Run in and Step Load

Oil Type: Mil-L-23699

T/C Thermocouples — Test Reduction Gear Brgs (25–30) — Slave Gear Unit Brgs (31–36)

Time	Start / Stop	25 Brg 1	26 Brg 2	27 Brg 3	28 Brg 4	29 Brg 5	30 Brg 6	31 Brg 1	32 Brg 2	33 Brg 3	34 Brg 4	35 Brg 5	36 Brg 6
Static		184	184	184	184	184		184	184	184	184	184	184
1205		185	186	185	184	185		185	184	185	184	184	184
1210	Stop												
1450	Start	184	18										
1455		184	184	184	185	185	185	185	184	184	184	184	184
1510		185	185	185	186	186	186	186	185	185	185	185	185
1520		186	186	186	187	187	186	186	186	185	186	186	186
1535		186	187	186	188	188	187	187	186	186	186	186	186
1545		187	187	187	189	189	188	188	188	187	187	188	187
1555		188	188	188	188	189	188	189	189	188	188	189	189
1610		220	219	225	230	230	232	227	230	221	221	226	215
1625		203	204	203	204	204	204	211	213	212	210	213	211
1640		203	205	203	205	205	205	213	214	217	212	214	212
1655		204	206	204	206	206	206	214	215	212	215	215	217
1715		212	214	212	214	214	214	226	227	226	224	227	225
1810	PM Stop												

Vibration Pickups - Mils

Time	1 Input Vert	2 Input Horiz	3 Input Box	4 Output Vert	5 Output Horiz	6 Output Box	7	8
1205	[illegible]	–	.004	–	.005	.004	.009	–
1455	.006	–	.004	–	.005	.004	.002	.001
1510	.002	–	.005	–	.002	.005	.002	.001
1520	.005	–	.007	.001	.002	.008	.003	.002
1535	.004	–	.009	.002	.006	.015	.006	.003
1545	.004	–	.009	.001	.005	.013	.005	.003
1555	.009	–	.009	.002	.015	.010	.005	.003
1610	.013	–	.035	.066	.033	.023	.011	.005
1625	.011	–	.020	[illegible]	.015	.020	.009	.005
1640	.011		.019	.0045	.014	.018	.007	.005
1655	.012		.017	.005	.013	.016	.007	.005
1715	.010		.016	.011	.007	.016	.008	.004

Move All Dec. Points 2 Places To Right Due To Error

(I/C Brown Erratic)

TESTER Durant

OBSERVER Farrell

Misel

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CURTISS-WRIGHT CORPORATION

POWER SYSTEMS LOG

TEST OBJECTIVE

DATE 11/24/75 STAND NO W427R ENGINE MODEL QCSEE NO UTW SHEET NO 4

OIL TYPE MIL-L-23699

CALCULATIONS:
INPUT POWER -
ELECTRICAL $P_E = \frac{V \cdot A}{746}$ HP
TORQUEMETER - $P_T = \frac{T \cdot N}{63{,}000}$ HP
GEAR SIMULATED POWER - HP = $\frac{\text{HYDR. PRESS} \times \text{RIG RPM}}{253.23}$

QCSEE MRG RIG BUILD NO 2
PROJECT NO 668414 , DEI QCSEE 9
UTW UNIT
REDUCTION GEAR BACK TO BACK,
RUN-IN AND STEP LOAD

Time	Start/Stop	Input power data	Oil pressure 1 · 2 · 3 · 4 · 5 · 6	°F Thermocouples 1–19 (oil in · oil out · dyn. · brg.)	Potter meters 1–5	Vib. 1 · 2
	Static					
	Static		[illegible] 280 85 [illegible] 470 250	170 183 87 181 178 182 182 73 182 94 158		
1205	Start 3		46 27 0 48 47 25	180 183 87 181 178 182 182 73 182 94 158 68 62 62 68 68 72 72 70		
1220	3					
1300		351 [illegible] 100 110 2171 980 891 21 971	45 27 0 48 47	Begin Test · 68 67 67 68 68 72 72 70	1208 1340 354 2760 — · 312 1340 157 310	
1315	4	585 [illegible] 150 146 1948 746 2257 21 [illegible]	45 27 0 48 47 .13	180 183 93 181 178 184 84 158 183 177 157 67 69 69 69 77 75 72 82	1207 1340 353 2760 — · 312 1340 158 310	.31 0
1330		585 [illegible] 150 146 1950 836 1631 106 [illegible]	45 24.9 0 48 47 13.5	182 185 85 183 179 189 188 138 184 186 157 68 66 67 70 85 81 75 89	1208 1340 355 1800 — · 312 1340 153 307	-.5 0
1350		1170 900 250 240 1890 1520 [illegible] 106 1428	45 26.3 0 48 47 23	182 186 92 183 180 200 190 138 185 188 157 69 74 79 72 89 84 77 93	[illegible] 1340 354 1800 — · 312 1340 151 307	.46 0
1355	Stop 5	1756 [illegible] 260 240 1895 2130 [illegible] 106 2479	45 26.2 0 48 47 27	184 186 [illegible] 183 180 200 201 120 185 200 162 70 82 83 76 94 93 80 96	1207 1340 356 2800 · 311 1400 152 307	.76 0
				185 187 [illegible] 185 182 218 220 103 187 207 167 76 86 89 77 106 106 88 103	1205 1340 356 2800 — · 311 1340 147 306	2.7 0
			Housing oil drain chip [illegible]	[illegible]tor signal; inspected and removed small machining chip		
1450	Start 5					
1500				Coast		
1505	Stop 5	1768 [illegible] 580 240 [illegible] [illegible] 106 [illegible]	46 26 0 48 46.8 27.2	185 [illegible] 185 181 217 220 107 181 207 166 65 85 88 77 106 106 88 102	1216 [illegible] 358 — · 314 157	2.3 0
			Motoring dynamometer prime mover cut out - inspected and restarted			
1520	Start 6					
1530	Stop 6					
11-25-75						
	Static			Cont Test		
				Open dynamometer jumper. Contaminated, removed, cleaned, inspected and reinstalled brushes & brush holders on #2 dyno also cleaned armature and ran in brushes approx 5 hrs		
0850	Start 5		46 27 - 48 42.5 0	180 181 - 175 176 178 179 74 172 99 164 78 79 79 78 76 76 76 76		
0855				Cont Test	1250 1340 357 2850 · 313 [illegible] 150 307	
0910		5700 [illegible] 40 72 1942 750 263 106 3129	46 27 - 49 17.2 12.5	182 184 - 177 178 184 185 124 181 180 160 70 78 79 79 79 79 77 89	1225 1340 358 2800 — · 317 1340 151 307	.06 0
0925		4120 882 230 235 [illegible] [illegible] 9277 106 [illegible]	46 27 - 49 47.2 23.5	181 182 - 178 178 194 201 110 181 196 169 62 80 80 78 92 93 78 92	1225 1340 358 2800 — · 316 1340 149 306	.38 0
0940		1720 [illegible] 260 235 3800 2240 [illegible] 106 [illegible]	46 27 - 49 47.2 28.5	184 188 - 178 174 210 213 92 178 210 169 60 78 81 81 106 106 87 99	1223 1340 358 2800 — · 317 1340 150 306	2.1 0
0945	Stop 6	2065 [illegible] 266 235 6600 2530 2391 106 2727 3024	46 27 - 49 47.2 31	183 186 - 180 180 225 229 80 185 222 179 62 81 85 84 116 116 100 112	1227 1340 358 2800 · 316 1380 145 305	1.3 0
			#1 Chip detector shorted found - removed small machining chip. #2 chip detector shorted found - removed			
			Continue test			
1015	Start 6					
1035	Stop 6					
1045	Start 6					

ENGINEER
TESTER Dupar
OPERATOR Farrell
INSPECTOR

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(5)

CURTISS-WRIGHT CORPORATION

POWER SYSTEMS LOG

TEST OBJECTIVE

DATE 11-24-75 STAND NO W427R ENGINE MODEL QCSEE NO UTW SHEET NO 5

OIL TYPE MIL-L-23699

QCSEE MRG RIG BUILD NO 3
PROJECT NO 668414 , DEI QCSEE 9
UTW UNIT
REDUCTION GEAR BACK TO BACK
RUN IN AND STEP LOAD

* DRIVE END - INPUT BOX
ANTI DRIVE END - OUTPUT BOX
MOUNT PLATE - ANTI DRIVE END

Time	Start & Stop	Dyno 20	Dyno 21	Dyno 22	Dyno 23	°F Thermocouples 25	26	27	28	29	30	31	32	33	34	35	36	Vibration pickups Mils 1	2	3	4	5	6	7	8
	Static	67	67	62	67	183	184	184	184	184	183	183	183	184	184	184	184								
1205	Start																								
1220		74	74	73	73	185	185	186	185	185	185	185	185	185	186	186	186								
1300		72	74	73	74	188	189	189	190	190	189	189	188	188	189	189	189	0.2	.35	.35	0.0	.14	.35	.15	.11
1315		85	85	85	86	189	189	190	190	190	190	190	189	189	189	189	150	.37	.45	.7	.14	.54	.7	.32	.18
1330		90	91	91	90	200	200	201	201	200	200	200	200	200	200	200	200	1.5	.9	.9	.25	1.1	.9	.78	.3
1350		95	96	96	95	214	216	215	216	216	216	216	215	215	215	216	217	.72	2.4	1.5	.5	2.2	1.3	.6	.76
1355	Stop																	1.2	1.4	1.6	1.9	.9	1.6	.9	.48
						Housing oil drain chip detector signal; inspected and removed small machining chip																			
1450	Start																								
1500		93	94	96	95	214	216	215	216	216	216	216	215	216	216	215	216								
1505	Stop																	1.2	1.1	1.2	1.3	.6	1.2	.8	.42
						Dynamometer circuit breaker tripped; inspected and restarted																			
1520	Start																								
1530	Stop																								
11-25-75																									
	Static					184	184	185	184	185	185	184	184	185	186	186	186								
0855	Start	86	86	86	86	190	190	190	190	190	190	189	188	188	188	189	188								
0910		88	88	87	88	202	198	198	198	197	197	197	196		197	196	195	1.6	0.8	0.9	0.2	0.9	0.9	0.8	0.3
0925		90	91	90	90	210	214	214	214	214	213	213	212		204	206	210	0.8	2.4	1.4	0.5	2.4	1.2	0.6	0.2
0940		94	94	94	95	230	228	228	225	225	224	224	224		218	219	220	1.2	1.4	1.2	2.0	0.9	1.3	0.7	0.4
0945	Stop																	1.1	1.4	1.2	1.0	0.9	1.3	0.7	0.4
1015	Start																								
1035	Stop																								
1045	Start																								

ENGINEER
TESTER Dupar
OPERATOR Farrell
INSPECTOR

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TEST OBJECTIVE Reduction Gear Back to Back PROJECT NO. 668414
Run in and Step Load

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 11-25-75 STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. 6

1045	Start																																														
1100		[illegible]	582	361	150	150	1946	850	269	108	3224	46	26	-	49	47	22.6	178	179	-	176	174	183	183	157	173	184	160	67	84	85	88	112	108	84	110	1225	11600	361	3000	—	316	11500	141	303	.45	0
1115			587	361	150	150	1946	340	289	212	3241	46	26	-	49	47	22	179	181	-	177	173	182	182	151	178	183	173	57	86	86	86	102	94	80	100	1227	11600	361	3000	—	316	11500	145	305	.50	0
1135			1170	995	300	235	2892	2580	976	212	3238	46	26	-	49	47	23	180	183	-	178	176	198	199	120	180	194	158	54	82	82	82	94	93	80	95	1226	11600	361	3000	—	317	11500	148	306	.8	0
1150			1170	1183	600	235	2840	2236	1308	212	4986	46	26	-	49	47	28.5	183	185	-	180	180	220	222	102	180	215	171	55	84	84	85	104	105	92	104	1222	11600	361	3000	—	316	11500	141	303	1.5	0
1200			1170	1181	600	235	2840	2276	70	212	4986	46	26	-	49	47	28.5	181	185	-	180	172	220	222	100	180	218	175	54	82	82	83	102	107	94	104	1222	11600	361	3000	—	316	11500	141	303	1.6	0
1200	Stop	[illegible]	Scheduled inspection of sungear																																												
			Sun gear inspection satisfactory - Continue test																																												
1825	Start	[illegible]																																													
1900			825	366	150	150	1948	840	275	212	164	46	26.5	-	48	470	13.5	181	183	-	180	178	188	188	126	182	185	161	79	89	86	83	91	86	80	96	1212	11450	358	2790	—	314	11500	156	310	.42	0
1915			-	366	150	150	1948	1070	33	318	2940	46	26.5	-	48	470	12.3	180	182	-	180	178	188	188	129	182	187	163	82	88	90	86	94	88	80	98	1212	11450	358	2790	—	314	11500	145	304	.45	0
1940			-	945	300	235	3880	1690	164	318	[illegible]	46	26	-	48	470	24.0	182	184	-	182	178	200	201	113	182	200	168	85	92	98	89	102	98	87	102	1210	11400	358	2790	—	314	11500	149	306	.85	0
2000			-	1968	625	235	5817	2360	167	318	7289	46	26	-	48	470	27.5	182	184	-	182	178	220	222	100	185	220	172	70	95	106	90	116	115	99	113	1210	11400	358	2790	—	314	11500	153	308	1.5	0
2010			-	1983	620	235	5817	2360	167	318	7289	46	26	-	48	470	30.0	183	186	-	182	179	221	223	100	184	221	176	70	96	108	92	120	119	103	116	1210	11400	358	2790	—	314	11500	144	304	1.4	0
2020	Stop	[illegible]	Scheduled inspection of sun gear																																												
11-26-75			Sun gear inspection satisfactory - Continue test																																												
1030	Start	[illegible]																																													
1045		[illegible]	578	345	160	170	1946	1130	349	320	3459	46	27	-	49	47	14.5	182	185	-	182	181	191	190	84	185	187	158	82	85	86	84	99	87	81	96	1216	11590	359	2800	—	314	11500	154	310	.5	0
1100			578	456	200	170	1946	1320	407	424	3288	46	27	-	49	47	15.0	183	186	-	184	180	193	192	87	185	184	160	75	87	88	84	94	90	83	99	1214	11450	358	2800	—	315	11500	156	310	.4	0
1115			1170	1183	350	235	3891	2860	1161	424	6654	48	26.5	-	49	47	23	185	188	-	184	181	205	206	88	182	202	162	71	88	89	84	99	98	86	100	1213	11475	359	2800	—	315	11500	152	311	.3	0
			Accelerate to 5837 RPM @ 424 Load: 100%																																												
1130			1170	1743	650	235	5837	2560	875	424	9993	46	26.5	-	49	47	27.5	185	188	-	186	182	226	227	90	184	223	171	71	91	95	87	115	115	99	112	1213	11475	359	2800	—	314	11500	150	306	1.8	0
1145		[illegible]	1170	2153	680	235	5837	2640	9417	424	9773	46	26.5	-	49	47	27.5	186	189	-	186	182	226	228	92	188	226	177	74	94	98	90	122	121	106	118	1214	11450	357	2800	—	314	11500	147	305	1.6	0
1155	Stop	[illegible]	Scheduled inspection of sun gear																																												
			Sun gear inspection satisfactory - Continue test.																																												
1450	Start	[illegible]																																													
1505			578	454	200	170	1946	1320	4025	424	3258	46	26.5	-	49	47	29.0	184	185	-	183	180	191	190	87	184	184	161	85	90	92	90	100	98	86	102	1216	11590	358	2790	—	316	11500	158	311	.42	0
1520			585	456	200	170	1949	1530	4716	508	3730	46	26.5	-	49	47.5	12.0	185	186	-	183	180	193	194	88	184	190	161	75	91	92	90	101	96	87	104	1216	11590	358	2790	—	316	11500	154	310	.42	0
1535			1170	1134	360	235	3891	2060	1272	508	7860	46	26.5	-	49	47.5	24	182	183	-	182	178	204	204	90	181	203	163	73	92	93	90	106	104	91	105	1216	11590	360	2800	—	315	11500	158	306	.8	0
			Accelerate to 5837 RPM @ 508 Load - 120%																																												
1550	Stop	[illegible]																																													
1655	Start	[illegible]																																													
1725			1170	1228	390	235	3880	2060	1271	508	7880	46	26.5	-	49	47.5	24	181	183	-	180	177	204	204	84	180	203	162	68	90	92	88	108	105	92	106	1217	11475	359	2800	—	315	11500	161	315	0.8	0
1740			1775	1205	700	235	5817	2750	2547	508	[illegible]	46	26	-	49	47.5	29	182	182	-	181	178	225	226	88	183	224	172	70	94	96	91	122	121	105	118	1211	11475	359	2800	—	314	11500	161	315	1.6	0
1755		[illegible]	1775	1205	700	235	5817	2750	2556	508	[illegible]	46	26	-	49	47.5	30	182	184	-	181	178	225	226	90	181	225	178	72	96	100	94	128	127	112	122	1210	11400	359	2800	—	314	11500	161	315	1.2	2
1810	Stop	[illegible]	Scheduled inspection of sun gear																																												

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER		[illegible]	
TESTER	Dugan	[illegible]	
OBSERVERS	[illegible]	[illegible]	
INSPECTOR			

TEST OBJECTIVE Reduction Gear Back to Back PROJECT NO. 668414
Run in and Step Load

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 11-25-75 STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. 7

Time of Day	Start • Stop	Dyno 20	21	22	23	Test Reduction Gear 15 #1	18 #2	27 #3	28 #4	29 #5	30 #6	31 #7	Slave Gear Unit 32 #8	33 #9	34 #10	35 #11	36 #12	1	2	3	4	5	6	7	8
1045	Start																								
1100		93	92	94	95	185	183	182	181	182	182	182	182	-	181	182	182	1.1	.07	1.4	.02	.08	1.4	.07	.03
1115		93	93	94	95	186	186	186	186	186	186	186	186	-	180	180	180	.07	.06	1.2	.02	.04	1.2	.06	.03
1135		92	92	93	94	200	200	200	200	200	200	200	200	-	198	197	197	.07	1.6	1.1	.05	1.8	1.0	.05	.03
1150		94	98	99	100	219	219	219	219	219	219	219	219	-	208	208	209	.09	1.1	.06	.07	1.2	.07	.06	.03
1200		90	89	96	99	212	212	212	212	212	212	212	212	-	204	204	204	1.2	1.0	1.2	.07	.08	1.2	.07	.03
1200	Stop																								
1825	Start																								
1900		93	93	94	94	188	188	188	189	189	188	187	187	-	187	187	187	.08	.07	1.5	.02	.06	1.5	.07	.03
1915		97	97	98	98	188	189	189	190	189	188	188	187	-	188	188	188	.05	.06	1.3	.02	.05	1.6	.07	.03
1940		102	102	103	101	200	200	200	200	200	200	200	200	-	200	200	200	.055	1.2	.09	.045	1.5	.08	.04	.035
2000		101	101	104	104	216	218	216	217	217	216	217	217	-	216	218	218	1.3	.09	1.0	.06	.08	1.0	.08	.035
2010		101	101	106	106	217	218	217	217	218	217	217	217	-	216	218	218	1.3	.09	1.1	.06	.07	1.0	.08	.035
2020	Stop																								
11-26-75																									
1030	Start																								
1045		93	93	92	92	192	191	192	191	191	191	192	192	-	190	190	190	.05	.05	1.6	.02	.04	1.6	.06	.03
1100		96	96	95	95	192	193	192	193	193	193	193	192	-	192	192	192	.06	.05	1.8	.02	.05	2.0	.09	.04
1115		98	98	97	97	206	205	205	206	206	205	205	205	-	204	206	206	.05	.09	.07	.04	1.4	.07	.04	.03
													Accel to 5837 RPM @ 424 Load												
1130		100	101	102	102	222	224	222	222	222	222	222	222	-	222	223	224	1.3	1.0	1.2	.07	.08	1.2	.08	.04
1145		103	103	104	103	222	224	222	222	223	223	223	223	-	222	224	224	1.2	.09	1.3	.07	.07	1.3	.08	.03
1155	Stop																								
1450	Start																								
1505		98	98	100	99	193	193	193	194	194	193	192	192	-	192	192	192	.04	.05	1.4	.05	.05	1.5	.06	.03
1520		100	100	101	101	195	195	195	195	195	194	194	194	-	194	194	194	.04	.05	1.4	.02	.05	1.5	.06	.03
1535		101	101	103	104	206	206	206	206	206	204	204	204	-	204	205	205	.05	.06	.09	.05	1.2	.08	.04	.03
1550	Stop																								
1655	Start																								
1725		99	99	101	101	206	206	206	206	206	206	204	204	-	203	204	205	.055	.055	.09	.04	1.2	.08	.04	.03
1740		101	101	105	106	221	222	220	220	222	221	221	221	-	220	222	222	1.3	.09	1.2	.07	.09	1.1	.08	.04
1755		103	103	107	107	220	221	221	221	221	221	221	220		220	221	221	1.2	.08	1.2	.07	.08	1.1	.08	.04
1810	Stop																								

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER		[illegible]	
TESTER		[illegible]	
OBSERVERS		[illegible]	
INSPECTOR			

ORIGINAL PAGE IS
OF POOR QUALITY

Test Objective: Reduction Gear Back to Back Oil Scavenging Investigation
Project No. 66844

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

Date [illegible] Stand No. [illegible] Engine Model 6CSEE No. [illegible] Sheet No. 9

1730	Start	DEI 6CSEE-10														
1820		825	97.3	200	180	2000	1480	96.9	106	837	.56	.315	0	.59	.63	.165
1840		825	99.5	300	225	2995	1900	96.3	106	1235.7	.56	.310	0	.595	.53	.205
1855		825	121	450	225	4500	2280	97.7	106	[illegible]	.56	.305	0	.595	.53	.214
1915		825	149	600	225	5000	2600	[illegible]	106	[illegible]	.56	.300	0	.595	.53	.255
1935		825	297.8	820	225	5995	2930	2977	106	2965	.55	.295	0	.595	.53	.290
2000		825	313.9	875	225	[illegible]	[illegible]	2954	106	2974	.55	.295	0	.595	.53	.305
2020		825	296.6	950	225	6395	3030	3015	106	2889	.55	.290	0	.595	.53	.325
2035		825	307.6	1000	225	6600	3160	3309	106	3307	.55	.300	0	.595	.53	.336
2040	Stop	825	344	1100	220	6800	3400	3617	106	[illegible]	.55	.300	0	.595	.53	.336
12-8-75		DEI 6CSEE-10A														
0855	Start 16°															
0915																
0935		570	47.3	220	160	2000	1980	46.7	106	837	.55	30.0	0	.58	.525	.165
0955	17°	900	52.6	300	230	3000	2320	96.2	106	2513	.55	29.2	0	.580	.520	.20
1030	Shut 18°	1200	128.5	450	230	4000	2500	153.5	106	[illegible]	.55	29.5	0	.580	.519	.23
						6000										
1115	Start 18°															
1130		570				2000	546		106							
1140		600	47.3	220	60	2000	1560	97.8	106	891	.57	31	0	.60	.58	.160
1150		900	92.6	300	230	3000	2020	96.2	106	2313	.56	30	0	.59	.53	.200
1200		1200	[illegible]	450	230	4000	2250	2160	106	[illegible]	.56	29	0	.59	.53	.230
1205	Stop	1335	155	600	230	4900	2320	2014	106	1826	.56	29	0	.59	.53	.240
						6000										
12-9-75		DEI 6CSEE-10B														
1555	Start															
1615		605	44.2	200	165	2000	1540	49.1	106	[illegible]	.455	.295	0	.575	.51	.165
1630		900	92.5	300	230	3000	1970	94.3	106	[illegible]	.455	.295	0	.595	.53	.200
1645		1205	159.4	500	230	4000	2380	151.2	106	[illegible]	.455	.290	0	.595	.53	.225
1705		1505	175.0	600	230	5000	2730	246.6	106	[illegible]	.455	.285	0	.595	.525	.238
1725		1825	297.5	900	230	6000	3150	300.1	106	[illegible]	.455	.270	0	.595	.525	.250
1740		1895	326	1000	230	6200	3280	314.2	106	[illegible]	.455	.275	0	.592	.528	.250
1755		1825	271.5	900	230	6000	3160	[illegible]	106	2586	.455	.278	0	.595	.520	.250

1820	100	100	-	99	99	108	106	90	100	95	95	66	68	68	68	84	84	77	90	1200	1130	345	2650		
1840	100	100	-	100	98	117	117	87	102	101	96	64	76	78	74	99	95	84	100	1203	1190	348	2700		
1855	101	101	-	100	100	125	126	82	100	105	98	64	76	77	76	106	103	90	103	1204	1200	347	2710		
1915	100	100	-	99	99	134	137	85	104	110	105	67	78	80	80	114	113	99	110	1210	[illegible]	355	2760		
1935	102	102	-	102	101	149	151	88	110	121	110	73	84	92	84	124	122	106	117	1220	1180	355	2760		
2000	103	103	-	102	102	153	155	89	112	126	113	76	87	93	87	128	127	110	120	1219	[illegible]	358	2790		
2020	106	106	-	103	104	158	162	100	110	130	119	81	91	98	92	133	133	115	124	1222	1260	358	2790		
2035	107	107	-	105	105	160	164	106	[illegible]	132	126	85	92	98	95	134	134	116	125	1224	1260	[illegible]	[illegible]		
2040	108	109	-	108	108	167	172	108	114	140	126	87	96	106	99	138	138	121	129	1210	[illegible]	357	2780		
0935	100	101	-	100	99	110	111	85	101	98	100	68	67	70	69	80	78	72	84	1176	1185	358	1710		
0955	101	101	-	100	99	118	120	80	101	103	104	60	71	73	70	92	87	76	93	1193	1130	352	1730		
1030	100	101	-	100	95	127	132	79	102	108	110	62	73	75	71	101	98	83	98	1200	1135	355	2760		
	Scav Gear Unit Sump Temp. Rose to 160° – Shut To Analyze Data																								
1130	95	96																							
1140	100	100	-	98	97	108	109	86	101	92	96	54	78	80	74	88	84	74	92	1185	1130	357	2730		
1150	101	102	-	100	99	118	120	82	102	100	102	54	79	81	75	96	88	76	94	1207	[illegible]	356	2760		
1200	100	101	-	100	98	127	133	79	103	106	108	53	80	82	76	97	95	80	95	1209	[illegible]	357	2780		
1205	101	101	-	101	100	132	140	80	104	110	118	54	80	82	76	102	100	85	98	1211	1175	360	2800		
	Shut To Analyze Data																								
1615	100	100	-	100	98	109	109	85	101	96	90	57	69	69	67	81	78	70	86	1205	[illegible]	353	2700		
1630	101	101	-	100	98	118	119	82	102	103	91	57	69	71	68	90	86	75	93	1207	1150	356	2700		
1645	100	101	-	100	98	127	129	80	102	107	98	57	71	74	70	97	94	80	96	[illegible]	[illegible]	357	2750		
1705	100	100	-	99	99	131	140	81	103	114	108	61	75	79	74	110	106	90	104	1207	1190	[illegible]	[illegible]		
1725	101	101	-	100	99	148	159	85	106	123	121	67	78	84	79	119	117	100	111	1207	[illegible]	360	[illegible]		
1740	101	102	-	101	100	152	168	88	108	126	130	71	81	87	82	123	122	105	115	1207	[illegible]	360	[illegible]		
1755	100	100	-	99	98	147	158	91	105	125	124	75	84	90	86	125	124	107	117	1203	[illegible]	357	2790		

1820	-	317	[illegible]	82	220	.63	0
1840	-	317	[illegible]	105	260	.64	0
1855	-	317	[illegible]	[illegible]	217	.57	0
1915		319	1170	102	248	.28	0
1935		319	1130	108	260	.16	0
2000		320	1150	105	260	.13	0
2020		322	1150	100	272	.14	0
2035		324	[illegible]	96	278	.14	0
2040		324	1140	110	266	.16	0
0935		317	1150	123	[illegible]	.52	0
0955		315	1120	131	[illegible]	.75	0
1030		317	1130	125	277	0.7	0
1140		323	1155	103	249	.42	0
1150		320	1110	101	248	.7	0
1200		319	1136	92	250	.7	0
1205		320	1135	95	250	.2	0
1615	-	320	1150	121	270	.38	0
1630	-	319	1150	119	267	.66	0
1645	-	319	1130	116	265	.56	0
1705	-	319	1130	116	265	.31	0
1725	-	320	1175	116	265	.19	0
1740		320	1175	116	265	.14	0
1755		320	1150	108	[illegible]	.16	0

	1st Shift	2nd Shift	3rd Shift
Engineer	– Mizer –		
Tester	Dunaway	[illegible]	
Observers	Fennell	[illegible]	
Inspector			

Test Objective: Reduction Gear Back to Back Oil Scavenging Investigation
Project No. 66844

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

Date [illegible] Stand No. [illegible] Engine Model 6CSEE No. [illegible] Sheet No. 9

1730	Start																
1755		70	70	76	76	113	113	114	116	116	115	115	110	110	110	112	112
1820		86	86	84	84	121	123	122	122	124	124	118	118	118	119	119	119
1840		88	89	89	88	134	134	134	134	134	134	125	124	123	123	124	124
1855		90	90	91	91	140	142	135	142	143	142	137	137	137	137	138	138
1915		94	94	96	96	150	153	149	153	154	153	146	147	147	146	147	147
1935		97	97	100	100	153	157	153	157	158	157	150	150	150	150	150	150
2000		101	101	106	106	157	161	156	161	162	162	154	154	154	154	154	155
2020		106	105	111	111	160	164	160	164	166	166	158	158	157	158	159	160
2035		108	108	115	113	164	167	162	166	170	168	161	161	162	162	162	163
2040	Stop																
12-8-75		DEI 6CSEE-10A															
0855	Start																
0915		74	74	73	72	111	112	112	113	114	113	110	109	109	110	110	110
0935		79	79	77	78	120	121	120	121	123	122	116	117	117	117	118	118
0955		81	81	81	81	129	130	129	131	133	131	126	126	127	127	127	127
1030	Stop																
Static Bore Rdg																	
1130		92	92	93	94	110	111	111	111	112	112	108	108	108	108	108	108
1140		92	92	94	94	120	122	120	121	123	122	118	118	118	118	119	118
1150		91	91	94	95	128	130	129	130	132	130	126	126	126	126	127	126
1200		92	91	95	95	133	135	133	135	137	136	132	132	132	132	133	133
1205	Stop																
12-9-75		DEI 6CSEE-10B															
1555	Start																
1615		74	74	73	72	111	112	111	113	113	113	109	109	109	109	109	109
1630		79	79	77	77	120	122	120	121	123	123	117	117	117	117	118	118
1645		81	81	80	80	128	131	129	130	132	131	125	125	126	126	126	126
1705		84	84	85	85	134	138	135	138	140	139	134	134	134	134	135	135
1725		89	89	91	91	147	150	147	151	153	151	146	146	146	146	146	147
1740		93	93	96	96	150	154	150	154	156	155	152	152	154	153	152	153
1755		93	95	100	100	146	150	146	150	152	150	145	145	146	146	145	146

1755	12	06	08	02	09	10	07	025	[illegible]								[illegible]
1820	04	13	06	01	12	08	03	035	86	145	150	200	120	115	110	10.0	306
1840	07	20	11	04	21	10	04	035	87	145	156	206	132	119	114	10.0	312
1855	09	11	13	06	11	13	06	045	131	151	159	213	149	124	123	10.0	314
1915	08	09	16	06	08	16	07	045	135	138	166	218	157	133	131	10.0	314
1935	08	11	15	05	06	16	08	04	147	170	180	224	170	148	147	[illegible]	316
2000	03	12	08	06	02	10	05	04	154	176	180	240	176	155	157	10.0	319
2020	12	15	12	08	10	13	07	04	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.0	316
2035	12	17	15	06	09	17	03	04	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.0	316
2040									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.0	313
0935	10	06	08	02	09	08	06	03	134	156	145	189	136	122	133	10.0	297
0955	04	13	04	03	13	07	04	025	131	153	163	203	148	153	149	10.0	301
1030	08	20	11	04	21	11	05	04	159	158	180	232	155	179	150	10.0	310
Static Bore Rdg									97	97	119	163	144	117	95	10.0	[illegible]
									45	45	166	265	156	163	145	10.0	290
1140	09	05	05	02	09	05	06	02	147	164	162	205	157	164	[illegible]	10.0	[illegible]
1150	04	13	07	03	13	06	04	03	175	175	173	230	172	173	[illegible]	10.0	[illegible]
1200	09	20	10	04	23	10	05	02	169	173	233	256	[illegible]	156	156	10.0	305
1205	07	08	08	04	09	09	04	03	317	345	332	[illegible]	[illegible]	[illegible]	371	49.0	[illegible]
1615	10	06	12	02	09	12	07	03	310	157	210	210	158	179	324	9.2	[illegible]
1630	05	13	06	01	13	08	04	02	310	179	210	219	170	160	326	9.2	[illegible]
1645	08	18	10	04	21	10	05	02	317	193	229	238	180	159	309	9.4	[illegible]
1705	10	11	14	07	12	15	08	03	327	196	237	259	190	176	[illegible]	9.1	[illegible]
1725	07	09	10	06	07	11	06	04	354	272	284	319	351	290	300	9.0	[illegible]
1740	07	09	09	05	06	08	06	04	418	443	430	427	433	[illegible]	420	91	[illegible]
1755	09	09	12	06	07	11	06	04	410	384	429	420	349	341	409	95	[illegible]

	1st Shift	2nd Shift	3rd Shift
Engineer	– Mizer		
Tester	[illegible]		
Observers	[illegible]		
Inspector			

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

TEST OBJECTIVE Reduction Gear Back to Back
Run in and Step Load

PROJECT NO. 668414

Oil Type Mil-L-23699

DATE 6-9-75 STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. [illegible]

Time	Start & Stop
1815	
1825	
1835	
1850	
1855	Stop

Improved Data – Removed Unit to A35?4

ENGINEER [illegible]
TESTER [illegible]
OBSERVERS [illegible]
INSPECTOR

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

TEST OBJECTIVE [illegible] Back to Back
Oil Screening Investigation

PROJECT NO. 66844

DATE 6-9-75 STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. [illegible]

Vibration

Magnetometers

Time	Start & Stop
1815	
1825	
1835	
1850	
1855	Stop

ENGINEER [illegible]
TESTER [illegible]
OBSERVERS [illegible]
INSPECTOR

CURTISS-WRIGHT CORPORATION

POWER SYSTEMS LOG

TEST OBJECTIVE

QCSEE PAG RIG BUILD NO. 4

PROJECT NO. 465414 DEI QCSEE XII

STA UNIT

REDUCTION GEAR BACK TO BACK

~~[illegible]~~

OIL SCAVENGING INVESTIGATION

CALCULATIONS:

INPUT POWER

ELECTRICAL $P_E = \frac{V \cdot A}{746}$ HP

TORQUEMETER $P_T = \frac{T \cdot N}{63000}$ HP

GEAR SIMULATED AIRCR.

H.P. = [illegible] 253.23

DATE 1-9 [illegible] SHEET NO. 12

CURTISS-WRIGHT CORPORATION

POWER SYSTEMS LOG

TEST OBJECTIVE

DEI QCSEE - II BUILD NO. 4

PROJECT NO. 465414

REDUCTION GEAR BACK TO BACK

OIL SCAVENGING INVESTIGATION

DATE 1-3-76 [illegible] SHEET NO. 13

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CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

TEST OBJECTIVE [illegible]

PROJECT NO. 669419

DATE [illegible] STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. 14

TIME OF DAY		
1110		[illegible]
1125		[illegible]
1140		[illegible]
1155		[illegible]
1157		[illegible]
1155	[illegible]	[illegible]
1425	[illegible]	[illegible]
1440		[illegible]
1455	[illegible]	[illegible]
1510	[illegible]	[illegible]
1525		[illegible]
1530		[illegible]
1540		[illegible]
1555		[illegible]
1600		[illegible]
1615	[illegible]	[illegible]

	1st SHIFT	2nd SHIFT	3rd SHIFT
ENGINEER		[illegible]	
TESTER		[illegible]	
OBSERVERS		[illegible]	
INSPECTOR			

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

TEST OBJECTIVE [illegible]

PROJECT NO. 669419

DATE [illegible] STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. 15

TIME OF DAY		
1110		76, 76, 75, 75
1125		83, 84, 83, 82
1140		91, 91, 91, 90
1155		96, 96, 96, 96
1170		101, 101, 101, 101
1155	[illegible]	
1425	[illegible]	
1440		[illegible]
1455	STOP	
1510	Start	
1525		
1530		[illegible]
1540		[illegible]
1550		[illegible]
1600		[illegible]
1615	STOP	

	1st SHIFT	2nd SHIFT	3rd SHIFT
ENGINEER		[illegible]	
TESTER			
OBSERVERS			
INSPECTOR			

#16

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FORM 642 REV 5-75

CURTISS-WRIGHT CORPORATION
POWER SYSTEMS LOG
TEST OBJECTIVE

DATE 1-21-76 STAND NO WX 27R ENGINE MODEL QCSEE NO UTW SHEET NO 16

QCSEE MAG RIG BUILD NO. 45
PROJECT NO ~~668--~~ 668437 DCI QCSEE-Ⅱ 12
UTW UNIT
REDUCTION GEAR BACK TO BACK
~~RUN IN + STEP LOAD~~
OIL SCAVENGING INVESTIGATION

OIL TYPE MIL-L-23699

CALCULATIONS:
INPUT POWER -
ELECT - $\frac{P_f \cdot V \cdot A}{746}$ HP
TORQUEMETER - $P_T = \frac{T \times N}{63000}$ HP
GEAR SIMULATED POWER
$H.P. = \frac{\text{HYDR. PRESS.} \cdot \text{RIG RPM}}{253.23}$

Time of Day	AM or PM	Start & Stop	Time Total	End	[illegible]	KW 746 HP	Total Amps	Volts	Rig RPM	[illegible]	[illegible]	[illegible]	HP
0935	AM		STATIC										
1040	·	Start	0^{45}			37.2	150	181	2018				
1100	·					37.2	150	181	2018	1020	31.7	2.2	1689
1115	·					100.5	300	250	4000	1360	1092	2.2	3349
1130	·					201.8	620	250	6000	2040	2160	2.2	4013
1145	·					292.6	880	248	7000	2840	2756	2.2	5560
1200	PM	Stop	1st										

Time of Day	Oil Pressures					
0935	47	27	0	50	48	2
1040	INCREASE	TO	2000 RPM	- Torque Load of 912 PSI		
1100	47	27	0	50	47	165
1115	47	26	-	51	47	24
1130	47	26	-	51	47	28
1145	47	26	-	51	47	33

Ve THERMOCOUPLES °F
STATIC OIL SCALE READING 50:1 ...

Time of Day	Oil In					Oil Out						Dyn				[illegible]				
0935	167	168	98	168	166	168	168	154	163	111	160	60	57	57	56	56	63	62	59	163
1100	163	162	83	162	152	170	169	127	164	117	160	64	61	62	62	70	69	66	76	157
1115	162	165	80	165	153	182	183	110	163	181	166	64	66	67	64	86	86	73	86	164
1130	161	163	78	163	150	193	198	100	165	130	177	65	68	70	66	91	93	77	91	169
1145	162	164	82	164	157	204	209	102	166	144	192	71	73	76	71	107	110	91	108	179

Time of Day	Oil Flows										[illegible]	
0935	1212	1123	355	2076	-	-	316	1150	165	310	"6" Dia = 4.8"	
1100	1200	1140	358	2077	-	-	316	1150	157	290	.85	.85
1115	1200	1135	360	2080	-	-	316	1150	130	290	1.4	.5
1130	1200	1135	360	2080	-	.	316	1150	130	290	1.7	.5
1145	1200	1140	360	2080	-	-	316	1150	135	282	1.8	.82

ENGINEER M. Seel
TESTER Dupont

#17

FORM 642 REV 5-75

CURTISS-WRIGHT CORPORATION
POWER SYSTEMS LOG
TEST OBJECTIVE

DATE 1-21-76 STAND NO WX 27R ENGINE MODEL QCSEE NO UTW SHEET NO 17

DCT QCSEE-12 BUILD NO. 5
PROJECT NO 668437

REDUCTION GEAR BACK TO BACK
OIL SCAVENGE INVESTIGATION

OIL: MIL-L-23699

Ve THERMOCOUPLES °F

Time of Day	AM or PM	Start & Stop	20	21	22	23	25	26	27	28	29	30	31	32	33	34	35	36
																	"6"	Dia = 4.8"
0935	AM	Static					163	164	164	164	164	164	164	164	164	164	164	164
1040	·	Start																
1100	·		74	74	72	72	170	170	170	171	171	171	169	170	170	170	170	170
1115	·		76	76	75	74	181	181	181	181	181	181	180	180	181	181	181	181
1130	·		80	80	78	78	197	197	196	198	198	199	197	199	199	198	200	199
1145	·		87	87	86	86	210	212	208	209	212	212	211	213	213	211	215	213
1200	PM	Stop																

VIBRATION PICKUPS - MILS.

Time of Day	Input Box 1	2	3	Output Box 4	5	6	[illegible]	[illegible]	Oil [illegible]		1	
0935	-	-	-	-	-	-	-	-	Cold	501		
1040									Hot	356	[illegible]	[illegible] Full
1100	.24	.35	.60	.13	.45	.60	.90	.15	2000	160	2000	5% "
1115	.32	.35	1.6	.45	1.8	1.5	.70	.22	4000	352	3000	5% Full
1130	.64	.90	.4	.50	.56	.40	.16	.10	6000	357	6000	Trickle
1145	.69	1.4	1.0	.65	.55	1.0	.12	.30	7000	347	7000	0 Flow

Time of Day	6(c)		2			3		4		5		6 a)		(a)	
1040	[illegible]	[illegible]	Stopped	Hot	95% Full	Hot	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1100	2000	[illegible]		2000	[illegible] Full	4000	[illegible]	3000	[illegible]	2000	[illegible]	[illegible]	[illegible]	2000	[illegible]
1115	4000	[illegible]		3000	10% Full	5000	Full	4000	[illegible]	4000	[illegible]	[illegible]	[illegible]	3000	[illegible]
1130	6000	[illegible]		6000	Mist	60-0	Full	6000	"	6000	[illegible]	[illegible]	[illegible]	6000	[illegible]
1145	7000	Full		7000	Mist	7000	Full	7000	"	7000	[illegible]	7000	Full	7000	[illegible]

ENGINEER M. Seel
TESTER Durant

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OF POOR QUALITY

No 18

CURTISS-WRIGHT CORPORATION

POWER SYSTEMS LOG

TEST OBJECTIVE

OIL TYPE: MIL-L-23699

CALCULATIONS:
INPUT POWER
ELECTRIC - Pe = V × A HP / 746
TORQUEMETER - PT = T × N HP / 63000
GEAR LOAD SIMULATION POWER -
H.P. = HYDR PRESS × RIG RPM / 253.23

QCSEE-[illegible]
PROJECT NO 668436 BUILD NO. 5A *5B
UTW UNIT
REDUCTION GEAR BACK TO BACK -
~~[illegible] STEP [illegible]~~
OIL SCAVENGING AND GEAR CONTACT INVESTIGATION

DATE 1-28-76 STAND NO. [illegible]-37A ENGINE MODEL QCSEE-[illegible] UTW SHEET NO. 18

TIME OF DAY	START & STOP TIME	POWER / RPM / HP	OIL PRESSURES	THERMOCOUPLES °F OIL IN	OIL OUT	DYNAMOMETER	FACILITY SPEED INCR.	OIL FLOWS	[illegible]
0915									
0920	START 0²⁰	STATIC OIL FLOW 50	46 27 0 50 47 0						
0925				161 161 0 161 144	161 161 113 1.0 116 157	65			
0950	STOP 0³⁰	[illegible] 378 175 170 2028 940 315 212 1692	46 27 0 50 46.5 16.5	161 162 0 162 145	167 167 114 162 119 157	67 65 66 65	71 71 67 77 70	1192 11200 352 2350	315 11600 141 305
1135	START 0⁵⁰			161 162 0 162 145	167 167 114 162 119 157	67 65 66 65	71 71 67 77 70	1196 11200 352 2350	312 11600 145 310
1200		300	GEAR INSPECTION					1196 11200 352 2350	312 11600 145 310 .35 .27
1215		606 378 155 180 2024 980 340 212 1694	51 27 0 55 45.5 2	160 161 83 162 152	167 167 100 161 114 1				
1230	STOP 1⁴⁵	1213 985 300 245 4000 1250 1110 212 3348	47 27 0 50 46.5 15	160 161 73 162 152	167 167 100 161 114 152	65 70 70 67	76 76 69 81 [illegible]		
1425	START 1⁴⁵		47 26.5 0 50 46.5 25	161 162 80 162 157	180 181 101 162 126 164	72 72 78 65	86 86 74 84 171	1206 11800 357 [illegible] 1202 11800 357 [illegible]	
1445			GEAR INSPECTION						
1500		1214 985 300 245 [illegible] 1250 1108 212 3313	47 26.5 0 51 46.5 35.5						307 1160 150 315 .22 .20
1515	STOP 2⁰³	1888 2026 640 240 [illegible] 2400 337 212 5813	47 26.5 0 51 46.5 41.0	161 162 80 161 151	180 181 98 162 125 164	77 77 77 78	92 92 80 92 166		317 11800 155 280 1.6 .95
1725	START 2¹⁵			160 163 81 161 148	201 202 99 163 139 179	82 80 83 75	103 104 91 99 190		
1755			GEAR INSPECTION					1206 11900 355 2500	
1820		1875 2011 625 240 6229 2340 231 106 2607	49 27 0 52 48.5 21.5					1208 11900 357 2500	317 1160 152 1.5 .37
1830	STOP 3²⁰	2300 [illegible] 2491 775 240 [illegible] 2680 2989 106 [illegible]	49 27 0 52 48.5 36.8	162 163 84 167 150	199 202 106 165 141 183	86 92 86 92	104 104 89 102 176		317 1180 148 1.7 .42
2-7-76			GEAR INSPECTION	163 164 93 164 150	213 216 103 166 153 192	91 88 93 88	117 118 101 111 188	1227 11600 365 2840 1234 11650 365 2840	322 11850 151 320 .09 .04 322 11850 149 307 1.0 .04
2110	START 3²⁰			D.E.I. QCSEE-12B BUILD 5B - DYNAMIC GEAR CONTACT INVESTIGATION - PROGRAM 668437					
2130									
2155		610 862 150 180 2018 1080 906 212 1489	46.5 27 0 51 46.8 15.0						
2220		1210 995 330 225 3993 1780 1128 212 3102	46.5 26.5 0 51 46.8 24.5	160 161 88 161 145	166 167 150 161 163 158	67 68 68 70	77 76 70 92 148		
2225	STOP 4³⁵	1818 2036 675 225 6000 2370 2256 212 5027	46.5 26.5 0 51 46.8 36.0	160 162 88 161 144	179 180 137 162 178 168	71 71 73 72	88 86 73 90 151	1209 11950 356 2760	315 11800 127 277 0.32 0.25
0845 2-8-76			GEAR INSPECTION -	SATISFACTORY 163 164 86 164 144	200 202 152 164 199 185	82 77 79 77	103 103 90 102 157	1209 11950 357 2800	315 11900 124 273 .4 .68
0930	START 4³³		47 27 50 47					1210 11800 360 2800	315 11900 119 270 1.2 0.25
0950	4³³			161 162 76 162 154	161 161 105 161 154 156	70 71 71 70	69 67 67 70 [illegible]	1211 11600 353 2760	315 11300 128 281
1025	5³⁰	1818 [illegible] 650 225 6005 2390 2265 212 6023	48 26.5 – 51 52.5 27.5	160 161 86 161 136	197 200 100 162 195 182	74 73 74 71	97 96 82 95 176	1211 11600 362 2775	316 11600 102 247 1.3 .47
		2123 2563 850 225 7000 2720 3421 254 7026	48 26.5 – 51.5 53 34	161 162 99 162 136	212 216 105 164 214 195	93 83 86 81	118 119 104 114 185	1218 11500 363 2800	317 11600 97 246 2.1 .6

ENGINEER M.I.SEL
TESTER [illegible] VREELAND
OBSERVER CARLSON
INSPECTOR

No 19

CURTISS-WRIGHT CORPORATION

POWER SYSTEMS LOG

TEST OBJECTIVE

PROJECT NO 668436 BUILD NO. 5A *5B
REDUCTION GEAR BACK TO BACK
OIL SCAVENGE INVESTIGATION

DATE 1-28-76 STAND NO. [illegible]-37A ENGINE MODEL QCSEE [illegible] UTW SHEET NO. 19

TIME OF DAY	DATE	START & STOP	THERMOCOUPLES °F 20	21	22	23	25	26	27	28	29	30	31	32	33	34	35	36	VIBRATION								OIL SCAV LBS
0915																											
0920		START	STATIC		BEARING		161	161	162	162	162	162	162	162	162	162	162	162									
0935			70	70	67	67	168	168	168	168	168	167	167	167	168	167	168	168									
0950		STOP																	.2	.72	.6	.13	.15	.52	[illegible]	.15	
1135		START																									
1200			80	80	77	77	167	167	168	168	168	168	167	167	168	168	168	168									
1215			84	84	82	82	180	181	180	180	180	181	179	180	180	179	181	180	.22	.4	.55	.14	.37	.6	.25	.15	
1230		STOP																	.36	3.5	1.8	.4	1.5	1.5	.6	.23	
1425		START																									
1445			87	87	85	85	180	180	180	180	180	180	179	180	180	179	181	180									
1500			90	90	89	89	198	199	196	198	198	199	197	198	198	197	201	199	.7	3.8	1.9	.95	.7	1.6	.52	.37	
1515		STOP																	.9	.9	.6	.55	.7	.6	.5	.2	
1725		START																									
1755			95	94	94	94	196	197	195	197	197	198	196	197	197	196	198	197									
1820			99	99	100	100	206	207	206	207	207	209	205	206	207	205	205	207	0.7	0.9	1.0	.6	0.7	0.9	0.6	0.3	
1830																			0.7	1.4	1.2	0.5	0.8	1.0	0.5	0.4	
2-7-76																											
2110		START																									
2130			73	72	72	72	167	167	167	167	167	167	166	167	167	167	168	167									
2155			79	79	79	78	180	180	179	180	179	180	179	180	180	179	181	180	0.8	0.6	1.0	0.12	0.3	0.5			
2220			86	86	86	86	197	198	196	197	198	198	197	198	198	198	200	198	1.6	4.6	2.6	0.6	2.3	2.3			
2225		STOP																	0.7	0.9	1.0	0.6	0.7	0.8			
0845	2-8-76																										
0930		START	73	73	74	73	161	162	162	162	163	162	162	162	162	163	163	162									
0950			82	82	81	81	195	196	194	195	196	196	195	196	196	196	198	196									336
1025			95	96	95	95	207	208	207	208	208	209	207	210	210	209	211	209	.96	.62	2.2	.46	.62	.82			
																			.82	1.8	4.6	.61	.67	1.4			

ENGINEER M.I.SEL
TESTER [illegible] VREELAND
OBSERVER CARLSON
INSPECTOR

2-8-76

TEST OBJECTIVE Dynamic Gear Contact Investigation PROJECT NO ~~668436~~ 668437

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 2-9-76 STAND NO W127R ENGINE MODEL QCSEE-12/13 UTW SHEET NO 20

Time of Day	Start & Stop	Time Start	End										1	2	3	4	5	C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Oil Flow								Facility	
1025 1640	Stop	5 30											GEAR INSPECTION - SATISFACTORY																																			
1235										Static Aq			47	275	-	51	53	0	159	160	82	160	148	160	160	145	159	164	155	87	85	84	84	55	75	73	94	161	1207	1140	356	2780	316	1180	103	250		
1300	Start	5 45																																														
1320				2125	2934	850	246	705	2670	2960	234	7026	47	275	-	51	53	31	161	162	92	161	134	211	210	107	163	219	144	76	86	67	84	110	112	96	107	184	1208	1160	360	2800	314	1180	106	250	2.3	.71
1355				2350	354	1100	246	7804	3030	375	276	8567	47	265	-	51	53	365	160	161	101	164	135	225	228	109	84	226	201	101	94	96	91	127	130	113	124	195	1212	1149	361	2815	315	1180	101	246	1.9	.45
1400	Stop	6 45											GEAR INSPECTION - SATISFACTORY																																			
1515	Start	6 45																																														
1535				2365	354	1100	246	7804	3000	371	276	8567	47	265	-	51	53	375	161	162	92	161	133	223	226	103	163	220	200	93	94	94	90	118	122	104	114	190	1204	1160	358	2790	314	1180	102	248	1.4	.27
1535	Stop	7 05											DYN OVERLOAD - TRIPPED																																			
1615	Start	7 05																																														
1625	Stop	7 15																																														
1630	Start	7 15											DYN OVERLOAD - TRIPPED																																			
1650				2485	3820	1120	252	8000	3131	4422	254	8215	47	265	-	51	53	39	160	161	47	165	132	227	236	114	163	223	262	96	98	94	94	118	123	104	116	182	1205	11450	358	2780	314	1180	102	248	1.7	.4
1655	Stop	7 45											GEAR INSPECTION																																			
2-11-76													DEI-QCSEE-12 SUM C W/O * 668441 - TORQUE METER CALIBRATION CHECK																																			
	[illegible]									106		60							69	69	64	70	69	70	70	70	70	69											[illegible]									
	[illegible]									106		47							69	69	69	70	69	70	70	70	70	70											1000									
1800	Start	7 40																																														
1825				1213	1072	320	250	4005	1610	823	127	2026	45	250	-	48	51	25	161	162	77	163	139	178	179	77	161	170	158	71	72	73	72	90	88	78	[illegible]	162	1170	1000	350	2720	305	1200	94	240	1.3	.85
1840				1218	922	275	250	4010	1370	872	127	2612	30.5	175	-	32	35	26	160	161	88	163	142	181	183	100	164	179	170	72	76	76	73	97	93	87	96	167	945	8832	286	2224	249	9250	80	215	1.8	1.2
1852				1577	1344	400	250	5204	1720	1410	108	2219	30.5	175	-	32	35	30	160	160	86	162	139	190	194	103	162	190	177	79	80	83	76	104	102	97	101	169	945	8832	286	2224	247	9260	73	207	2.4	1.6
1900				1578	1759	525	250	5210	1970	1619	108	2222	45	25	-	48	51	305	160	161	87	161	139	188	190	104	162	188	176	78	81	83	76	107	105	92	104	170	1170	11000	350	2720	305	1200	94	240	1.7	1.3
1920				1900	2217	675	245	6270	2540	2527	311	7700	45	25	-	48	51	342	161	162	89	163	144	204	207	108	164	204	187	77	84	87	78	113	113	100	109	179	1170	11000	350	2220	305	1200	99	244	1.7	.55
1940				2291	3262	975	245	7560	2910	3491	232	6926	45	25	-	48	51	378	161	162	93	162	142	220	227	104	164	220	198	78	88	91	82	121	118	107	116	190	1170	11000	350	2200	305	1200	94	240	.86	.20
1953				2293	1856	900	245	7566	2790	3350	272	6987	37	21	-	40	415	418	160	160	100	164	141	222	227	105	164	213	201	80	92	95	87	129	130	115	123	190	1085	9936	315	2400	276	1020	87	230	1.3	.22
2000	Stop	9 45																																														
2215	Start	9 45											GEAR INSPECTION - SATISFACTORY																																			
2230				2391	3186	970	245	7560	2810	3371	232	6926	45	25	-	48	51	36	162	163	96	164	150	220	224	94	165	217	190	72	88	91	85	115	117	100	109	190	1170	11000	350	2720	305	1120	102	248	1.1	.22
2245				2293	3346	1040	240	7567	3080	3698	406	12182	45	25		48	51	378	160	162	95	161	152	223	228	103	165	224	200	75	91	95	87	123	125	108	117	192	1170	11000	350	2700	305	1200	99	240	1.4	.25
2300	Stop	10 45											GEAR INSPECTION -																																			
2125	Start	10 45		2-24-76									DEI-QCSEE-13 BUILD 5C - [illegible] * 668441																																			
2145				1215	903	275	245	4010	1570	999	128	2027	41	225	-	44	475	278	161	162	93	162	138	179	181	134	164	177	169	71	73	74	74	87	87	77	100	160	1120	10500	337	2600	391	10500	94	240	.75	.44
2200				1223	903	275	245	4036	1400	910	128	2040	30	168	-	32	360	278	161	162	97	162	137	181	182	148	165	180	172	73	77	77	76	96	93	81	104	162	945	8832	286	2220	246	9100	68	190	2.0	.28
2215				1580	1317	400	245	5215	1670	1382	108	2224	30	168	-	32	36	310	160	161	99	161	137	191	194	146	164	191	178	76	81	82	80	104	102	89	105	174	945	8832	285	2200	246	9100	68	190	5.2	1.2
2225				1580	1395	425	245	5215	1850	1570	108	2224	41	218	-	44	475	313	161	162	98	162	139	190	192	158	165	190	182	74	84	85	82	107	105	92	110	175	1120	10500	377	2600	292	11000	85	220	5.2	1.1
2240				1901	2135	650	245	6273	2420	2419	311	7204	41	225	-	44	475	342	161	162	89	162	136	205	209	159	164	206	192	73	87	90	85	112	112	98	115	186	1120	10500	377	2600	292	1100	90	235	5.8	1.2
2250	Stop	11 50											GEAR INSPECTION																																			

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER	—	Mizel	—
TESTER	Dupont	[illegible]	
OBSERVERS	[illegible]	Carlson	
INSPECTOR			

TEST OBJECTIVE Dynamic Gear Contact Investigation PROJECT NO ~~668436~~ 668437

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 2-9-76 STAND NO WX-27R ENGINE MODEL QCSEE-12/13 UTW SHEET NO 21

Time of Day	Start & Stop	20	21	22	23	25	26	27	28	29	30	31	32	33	34	35	36	1	2	3	4	5	6	7	8	Oil
1640	Stop																									
1235	[illegible]	88	86	90	89	160	160	160	160	160	160	160	160	160	161	161										
1300	Start																									250
1320		98	98	98	98	207	208	207	207	208	208	206	209	209	209	210		.73	18	58	.65	79	1.4			
1355		110	109	109	110	207	208	206	218	216	220	217	220	220	215	222		1.7	1.2	7.8	.46	.52	2.3			
1400	Stop																									
1515	Start																									
1535		109	109	109	110	215	216	214	216	215	~~219~~ 217	216	219	219	217	220		1.4	1.5	2.4	.50	.73	2.8			
1535	Stop																									
1615	Start																									
1625	Stop																									
1630	Start																									
1650		114	114	114	114	219	220	219	220	219	222	220	222	223	220	224		1.4	1.9	3.8	.69	1.13	1.16			
1655	Stop																									
2-11-76		DEI QCSEE-12.C																								
1800	Start																									
1825		80	81	79	79	179	180	180	181	179	180	178	179	179	178	179	179	.83	.39	1.0	.57	.24	.21			
1840		83	83	82	82	183	182	183	182	180	182	181	182	183	182	184	182	1.4	.40	1.0	.55	.25	.23			
1852		87	87	86	86	190	191	187	189	188	191	189	190	191	190	191	191	1.3	1.5	.28	.55	.16	1.2			
1900		88	88	88	88	187	188	185	187	186	186	186	187	188	187	188	187	-	-	-	-	-	-			
1920		91	91	93	93	201	202	200	201	201	202	201	203	203	202	205	203	1.0	.09	.25	.04	.06	.06			
1940		97	97	99	99	213	214	211	212	214	215	213	216	216	214	217	215	.07	1.0	1.5	.06	.05	1.5			
1953		101	101	106	106	215	217	214	214	216	218	216	219	219	219	220	218	.09	1.3	1.7	.05	.056	1.9			
2000	Stop																									
2215	Start																									
2230		99	99	104	104	213	214	212	213	214	216	214	216	216	214	217	215	.08	1.0	2.0	.055	.055	2.1			
2245		103	103	108	108	217	219	216	216	218	219	217	220	220	218	222	219	.09	.09	1.8	.06	.05	2.4			
2300	Stop																									
2125	Start	2-24-76 DEI QCSEE-13																								
2145		80	80	78	78	181	181	181	182	180	181	179	180	180	180	181	180	.045	2.1	1.2	.04	1.4	1.1			
2200		83	84	82	82	183	183	183	184	182	183	181	182	182	182	183	182	.045	2.1	1.1	.04	1.4	1.0			
2215		89	89	88	88	191	192	190	193	190	192	190	192	192	192	193	192	1.6	1.7	4.0	.05	1.3	1.5			
2225		89	89	89	89	188	190	188	191	188	190	187	188	190	189	190	189	1.5	1.5	4.2	.05	1.2	1.2			
2240		94	94	94	94	203	204	204	206	202	204	203	205	205	205	206	205	3.6	2.4	6.0	.05	1.4	6.5			
2250	Stop																									

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER		Mizel	—
TESTER	Dupont	[illegible]	
OBSERVERS	[illegible]	Carlson	
INSPECTOR			

ORIGINAL PAGE IS
OF POOR QUALITY

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

TEST OBJECTIVE Dynamic Gear Contact Investigation PROJECT NO ~~668437~~ 668441

DATE 2-25-76 STAND NO WX-278 ENGINE MODEL QCSEE NO. UTW SHEET NO 82

Time of Day	Start Stop	Time Total	E-D	Dyn. RPM	Dyn. H.P.	Total Amps	Watts		Rig RPM	Torq Ind.	Slave Shaft H.P.	Torq	H.P.	1	2	3	4	5	6
0950	Start	1159							Static Log				62	36		65	65	0	
1020				1316	1181	460	250	5200	1860	1534	108	2118	42	26	-	46	46	29.5	
1030				2261	264	820	240	7560	2790	3547	232	6926	42	23.5	-	45	46	37	
1040				2201	2509	780	240	7560	2720	3262	232	6926	34	20	-	37	40	39.5	
1045	Stop	1255																	
0850	2-26-76																		
0855	Start	1255							Static Log				43	26	-	47	48	0	
0910				1575	1403	420	250	5200	1840	1518	108	2116	42	23	-	45	48	27	
0930				2261	2627	800	245	7560	2820	3513	232	6926	42	23.8	-	45	47.5	36	
0945				2291	3218	980	245	7560	3140	376	445	1325	42	23.8	-	45	47.5	39	
1000				2291	3217	980	245	7560	3140	376	443	1325	39	22.5	-	42	45	41.5	
1010				2358	3818	1060	242	7781	3280	445	443	1361	42	23.8	-	45	47	42	
1020	Stop	1420																	
1205																			
1215	Start	1420							Static Log										
1230				2291	2619	820	240	7560	2790	335	232	6926	42	23.8	-	45	47	35	
1250				2356	3603	1120	240	7781	3290	446	531	1636	42	23.8	-	45	47	37	
1255	Stop	1500																	
1445																			
1450	Start								Static Log				38	22	-	38	40		
1500				1212	843	260	242	4000	1410	895	128	2022	31	17.5	-	33	35	25.5	
1515				1212	843	260	242	4000	1410	895	128	2022	31	17.5	-	33	35	25.5	
1530				1212	843	260	242	4000	1420	895	128	2022	31	17.5	-	33	35	25.5	
1545				1212	843	260	242	4000	1420	895	128	2022	31	17.5	-	33	35	25.5	
1600		1610		1212	843	260	242	4000	1420	895	128	2022	31	17.5	-	33	35	25.5	
1615				1576	1378	400	242	5200	1720	1435	108	2218	31	17.5	-	33	35	27.0	
1630				1576	1448	450	240	5200	1870	1543	108	2217.5	41.8	22.8	-	45	46.8	29.5	
1645				1576	1449	450	240	5200	1880	1551	108	2217.5	41.8	22.8	-	45	47	29.5	
1700		1710		1576	1449	450	240	5200	1860	1535	108	2218	38.5	20.0	-	40	41.5	29.5	
1715				1576	1383	430	240	5200	1790	1479	108	2217.5	31.0	18.5	-	34	38	29.8	
1730				1576	1383	420	240	5200	1800	1485	108	2217.5	31.0	18.5	-	34	38	29.8	
1740																			
1800		1750																	
1820				1900	2188	680	240	6270	2140	2298	311	7304	40	24.5	-	44.5	47	31.2	
1845				2123	2018	775	200	7005	2580	2968	232	6497	39.0	19.5	-	37.5	39.5	36.0	
1855	Stop	1845																	

Time of Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	KPS	#/hr	KPS	#/hr	KPS	#/hr	KPS	#/hr	KPS	#/hr	Vibration	Vibration
0950	77	77	75	78	76	78	78	78	78	78	78										1216	11500	338	2520			323	1150				
1020	160	161	83	161	138	187	189	165	163	184	174	82	83	84	80	110	93	85	102	167	1124	10600	339	2630			295	10600	89	288	4.8	.85
1030	162	164	88	164	138	223	226	166	166	220	203	86	89	92	85	116	109	102	115	200	1120	10510	335	2600			294	10850	92	241	1.1	.7
1040	161	162	92	162	136	224	224	165	166	225	204	89	94	96	89	124	116	109	123	199	1015	9510	304	2360			266	9900	74	215	1.8	.26
1045																																
0850	GEAR INSPECTION - SUN & STAR GEAR INSP. - SATISFACTORY - SILVER PLATED SUN GEAR - REINSTALLED																															
0855	135	136	72	137	120	135	135	106	136	129	131										1122	10550	333	2510			294	10850	78	230		
0910	160	161	83	161	132	186	188	142	163	181	170	77	77	77	76	75	73	74	75	148	1124		339				294		89			
0930	160	161	83	161	132	186	188	142	163	181	170	78	78	78	75	90	73	80	93	164	1124	10600	339	2630			294	10850	89	258	.7	.22
0945	161	162	89	162	135	220	225	132	166	218	200	90	85	86	82	117	77	94	143	148	1124	10600	332	2600			294	10850	87	224	1.2	.17
1000	161	162	95	160	136	226	229	135	164	226	203	98	90	91	86	124	80	110	122	225	1124	10600	335	2600			294	10850	84	225	1.7	.25
1010	161	162	102	161	138	227	230	132	164	227	204	93	94	95	90	130	82	114	127	205	1091	10550	325	2420			365	11500	79	215	1.7	.25
1020	161	162	102	160	139	229	233	132	166	230	207	93	99	100	93	133	83	117	130	208	1135	10620	335	2600			294	10850	85	220	1.8	.50
1205	GEAR INSPECTION - OK TO RESUME TEST																															
1215	119	114	81	121	107	120	120	112	121	117	119										1125	10620	335	2600			298	10950	71	200		
1230																																
1250	161	162	98	162	135	[illegible]	228	112	[illegible]	216	187	89	96	98	94	118	80	103	117	176	1124	10600	336	2600			294	10850	94	247	1.4	.16
1255	160	161	97	163	136	[illegible]	235	121	[illegible]	[illegible]	207	93	102	105	98	130	83	115	127	190	1124	10600	335	2600			294	10850	87	224	1.6	.9
1445	GEAR INSPECTION - OK RESUME TEST																															
1450	116	116	83	118	104	117	117	110	118	114											951	9400	278	2150			253	9400	56	183		
1500																																
1515	160	160	84	160	130	176	178	117	159	170	161	87	98	98	95	116	86	92	108	149	950	9880	287	2230			249	9310	76	210	.78	.65
1530	160	161	87	160	135	178	180	118	161	177	169	86	98	98	95	108	86	92	107	157	950	9880	287	2230			249	9220	72	204	.82	.73
1545	160	160	88	161	135	179	180	122	162	178	170	88	98	98	94	108	86	91	107	161	950	9880	287	2230			249	9220	74	208	.64	.5
1600	160	161	90	160	136	178.5	181	123	163	179	171	89	98	98	95	107	87	91	107	161	950	9880	287	2230			249	9220	70	202	.65	.62
1615	160	160	90	163	136	180	182	124	164	180	171	89	98	98	95	107	86	91	106	161	950	9870	287	2230			249	9220	70	202	.65	.62
1630	160	161	88	162	135	190	192	122	163	189	176	90	98	99	95	[illegible]	95	93	107	171	950	9880	285	2230			249	9220	74	208	.53	.20
1645	161	162	89	162	137	189	192	130	166	190	179	91	99	102	96	113	98	97	111	175	1122	10560	289	2630			294	10850	92	241	1.8	.47
1700	161	162	100	162	134	190	192	158	165	190	182	102	100	101	96	113	98	98	112	175	1122	10560	389	2630			294	10850	92	241	1.0	.26
1715	161	162	101	162	133	190	192	143	166	191	178	105	100	101	96	113	98	98	112	176	1122	10560	389	2630			294	10850	92	241	1.7	.20
1730	161	162	102	162	133	182	194	154	164	191	180	105	99	100	96	113	99	98	112	173	968	9100	296	2300	999	4600	257	9300	84	225	1.9	.25
1740	161	162	102	162	137	182	194	157	167	191	182	106	99	99	96	113	99	98	111	173	968	9100	296	2300	996	4600	257	9300	84	225	1.9	.35
1800	CHECK - OK ON FUSION [illegible] - CLEAN																															
1820	162	163	88	163	137	206	210	148	165	206	189	90	98	99	94	114	114	99	112	186	1122	10560	377	2630			293	10850	92	241	3.6	.78
1845	160	161	98	164	137	217	221	149	165	219	201	95	102	104	98	128	128	113	124	198	1013	9100	302	2340			265	9150	77	212	.65	.15
1855	GEAR INSPECTION - OK TO RESUME TEST																															

	1st Shift	2nd Shift	3rd Shift
Engineer	—	Misel	—
Tester	Durant	V.F. Hanna	
Observers	Sando	E.A. Conner	
Inspector			

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

TEST OBJECTIVE Dynamic Gear Contact Investigation PROJECT NO 668437 668441

DATE 2-25-76 STAND NO 278 ENGINE MODEL QCSEE-12B NO. UTW SHEET NO 83

°F THERMOCOUPLES °F

Time of Day	Start Stop		Dynamometers #1 20	21	#2 22	23		Brg 1 25	2 26	3 27	4 28	5 29	6 30	7 31	8 32	9 33	10 34	11 35	12 36		Vibration Mils Input Vert 1	Horz 2	3	Output Vert 4	Horz 5	6	7	8	Oil
0950	Start																												490
1020			90	90	89	90		187	188	187	184	187	189	186	187	188	187	188	187										
1030			100	100	100	100		216	218	217	219	217	219	216	218	219	218	220	218		1.0	1.4	3.0	.52	1.2	1.2			
1040			104	104	105	104		216	218	218	210	217	219	217	219	220	220	220	219		1.2	1.0	1.6	.52	.45	3.2			
1045	Stop																				1.8	1.1	1.8	.50	.49	3.8			
0850	Static Log		78	78	78	78		142	143	144	145	144	144	143	146	146	146	146	143										
0855	Start																												
0910			83	83	83	82		187	188	187	190	188	189	186	187	188	187	188	188										
0930			96	96	94	94		214	216	215	218	216	217	214	216	217	216	218	216		2.1	1.4	1.2	.50	.62	1.2			
0945			103	103	102	101		219	222	222	223	221	221	219	223	222	221	221	221		.86	.92	2.0	.50	.48	2.1			
1000			107	107	107	107		222	223	223	224	224	221	220	224	223	223	225	225		.98	.88	2.1	.56	.52	2.1			
1010			111	111	112	113		221	225	225	226	224	224	223	225	226	224	228	224		.92	1.0	2.0	.58	.52	2.3			
1020	Stop																				1.1	1.2	1.8	.57	.42	2.9			
1205	Static Log																												
1215	Start																												
1230			109	109	112	112		214	216	215	218	215	217	214	216	217	216	218	216										
1250			116	116	120	120		224	226	227	228	225	226	225	228	228	226	230	226		.72	.80	1.8	.52	.48	1.5			
1255	Stop																				1.4	1.4	2.3	.53	.48	4.6			
1445	Static Log																												
1450	Start																												
1500			105	105	109	109		180	181	181	182	180	181	180	180	180	180	181	180										
1515			106	106	109	109		180	180	180	181	178	180	179	180	180	180	181	180		.46	1.6	1.2	.35	1.2	1.1			
1530			106	106	109	109		182	182	182	183	181	183	181	182	182	182	183	182		.49	1.7	1.6	.33	1.4	1.2			
1545			106	106	109	109		182	182	182	183	179	181	180	181	181	181	182	181		.50	1.8	1.7	.35	1.4	1.2			
1600			106	106	109	109		181	181	181	182	179	181	180	181	181	181	182	181		.52	1.7	1.8	.36	1.4	1.2			
1615			106	106	109	109		181	181	181	182	179	181	180	181	181	181	182	181		.52	1.8	1.8	.36	1.4	1.4			
1630			106	106	109	109		191	192	191	193	177	192	190	191	192	191	192	191		1.7	1.3	2.2	.06	1.0	1.0			
1645			106	106	108	109		188	190	188	191	-	191	187	189	189	189	190	189		1.7	1.1	2.1	.05	.08	1.0			
1700			106	106	107	108		189	190	185	191	-	191	188	189	190	189	190	189		1.7	1.2	2.0	.05	.09	1.1			
1715			105	104	106	107		190	191	190	192	-	192	189	190	191	190	191	190		1.7	1.2	2.0	.05	.09	1.1			
1730			105	104	106	107		191	193	191	193	-	193	191	192	192	192	193	192		1.5	1.1	2.2	.05	.08	.09			
1740	Stop							191	192	190	193	-	193	191	192	192	192	193	192		1.3	1.2	2.2	.05	.08	.09			
1800	Start																												
1820			107	106	107	109		204	205	204	206	-	205	208	205	205	205	207	205										
1845			112	112	116	116		211	213	213	214		214	211	214	213	215	215	213		1.3	2.4	3.0	.04	1.5	1.9			
1855	Stop																				.09	1.2	1.4	.06	.05	1.5			

	1st Shift	2nd Shift	3rd Shift
Engineer	—	Misel	—
Tester	Durant	Yeoung	
Observers	Sando	Cahill	
Inspector			

ORIGINAL PAGE IS OF POOR QUALITY

#24

TEST OBJECTIVE Dynamic Gear Contact Investigation PROJECT NO. 668441

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE Feb 26 '76 [illegible] ENGINE MODEL [illegible] SHEET NO. 24

Time of Day	Start & Stop	Time																1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20										
																		Gear inspection																													
2110	Start [illegible]																																														
2130			1578	1498	450	240	5607	1810	1495	108	[illegible]	41	23	-	45	484	388	160	161	84	159	128	186	188	106	161	182	172	83	95	96	91	107	106	92	106	164	1122	1086	338	2605	892	2030	97	340	1.2	.24
2150		2358	2390	1559	1100	240	7037	3160	3789	443	[illegible]	398	224	-	42	465	359	161	163	100	161	132	231	235	128	167	231	208	86	100	102	96	126	127	111	122	207	1092	[illegible]	325	2500	216	2000	85	325	1.7	.18
2200			2300	2378	1050	240	7500	3160	3806	443	[illegible]	398	224	-	42	465	368	161	161	106	164	133	229	232	106	166	229	207	85	103	106	99	133	131	116	128	208	[illegible]	[illegible]	325	2500	216	2000	85	324	.80	.10
2225			2356	[illegible]	1125	240	7775	3280	4170	443	[illegible]	410	225	-	444	480	375	161	162	104	160	134	230	233	140	167	231	208	84	107	109	104	136	137	120	131	208	1122	1056	334	2600	292	2030	87	329	1.7	.25
2235			2423	[illegible]	1208	240	7996	3380	4495	474	[illegible]	410	260	-	480	515	395	161	162	105	162	135	234	237	139	168	234	211	83	109	111	108	138	140	182	132	212	1170	1046	348	2700	304	2020	95	238	1.8	.25
2245	Stop [illegible]																	Test Completed																													

ENGINEER Misel

#25

TEST OBJECTIVE Dynamic Gear Contact Investigation PROJECT NO. 668441

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE Feb 26, 76 STAND NO. [illegible] ENGINE MODEL [illegible] SHEET NO. 25

Time of Day	Start & Stop	Dynamometer 20	21	22	23	T/C Thermocouples °F 25	26	27	28	29	30	31	32	33	34	35	36	Vibration mils 1	2	3	4	5	6
2110	Start																						
2130		104	104	107	107	186	187	186	188	-	188	185	186	187	186	187	186	1.6	1.4	1.4	.6	.9	1.0
2150		114	114	117	117	224	227	227	228	-	227	225	228	229	227	230	226	.9	1.3	1.6	.6	.5	1.1
2200		117	117	121	121	221	223	223	224	-	223	223	226	226	224	226	228	.7	.9	1.8	.6	.5	1.4
2225		120	120	125	125	222	225	225	226	-	225	223	226	227	224	228	225	.8	1.2	1.8	.6	.5	1.2
2235		123	123	129	129	225	228	228	229	-	228	226	229	231	227	232	228	.8	1.4	1.2	.6	.5	.9
2245	Stop												Test Completed										

ENGINEER Misel

APPENDIX E

OTW LOG SHEETS

#1

CURTISS-WRIGHT CORPORATION
POWER SYSTEMS LOG
TEST OBJECTIVE

DEZ QCSEE-15 BUILD NO. 6
PROJECT NO. 660445
Reduction Gear Back to Back, Run w/Step Load Survey
Lube Oil Type - Aeroshell Turbine Oil 555

DATE May 6, 1976 STAND NO. W1238 ENGINE MODEL QCSEE-15 NO. OTW SHEET NO. 1
MRG

Calculations -
Power Input:
Elect. - $\frac{V \cdot A}{746}$ = HP
Torquemeter - $\frac{T \times Rig\ RPM}{63{,}000}$ = HP
Gear Simulated Power -
$HP = \frac{Hydr.\ Press \times Rig\ RPM}{223.78}$

Time of Day	AM/PM	Start/Stop	Time						Rig RPM				HP
1620	PM	Start	0										
1700				STATIC READING									
1725					1190	1401	100	105	1180	650	127	190	100
1745					[illegible]	148	100	110	1200	560	108	190	101
1805					3031	838	250	250	3032	1860	595	740	[illegible]
1810	PM	Stop	1:50		3036	838	250	250	3032	1650	798	740	[illegible]
0925	AM	Start	1st	STATIC READING 5-7-76									
0955					918	855	250	255	3032	1920	925	740	[illegible]
1010		Stop	2:25										
1020		Start	2nd										
1040					[illegible]	545	245	[illegible]	4150	[illegible]	315	[illegible]	
1055					760	3384	1000	245	5805	3970	3457	315	[illegible]
1100	AM	Stop	3:45										
1510	PM	Start	3rd										
1530				Static Reading									
1540					1762	3217	1000	240	5715	5970	3667	3150	[illegible]
1555					1759	3056	950	240	5807	3700	3410	3150	[illegible]
1557					1765	3095	900	240	5828	3460	3200	3150	[illegible]
1600		Stop	3:57						5017	3460			
1110	AM	Start	3:57										
1130	AM	Start	4th	Static Reading 5-14-76									
1145					918	11.1	110	245	3633	1730	13.1	11.0	[illegible]
1200	PM				1938	[illegible]	1100	240	6600	3880	3900	3150	[illegible]
1215					1990	[illegible]	1200	240	6563	[illegible]	467	3150	[illegible]
1230	PM	Stop	5:05		1998	[illegible]	1250	240	6593	[illegible]	427	375	[illegible]
1350	PM	Start	5th	Static Reading - MIL-L-23699									
1410			5:5[illegible]		1988	359	1100	240	6600	3860	355	3150	[illegible]

OIL PRESSURES

Time of Day	1	2	3	4	5	6
1700	47	37	·	43	56	0
1725	46.5	275	-	42	56	9.5
1745	19.5	10.5	-	17	22	5.5
1805	47	265	-	42	555	2.5
1810	29	165	-	25	53	3.15
0925	For Sun Gear Inspection					
0955	46.5	260	-	420	570	3.15
1010	Emergency Stop - Dyn. Cut Out -					
1040	46.5	260	-	420	575	3.0
1055	40.0	21.0	-	360	475	3.15
1530	For Gear Inspection					
1540	39.5	21.5	-	360	475	[illegible]
1555	31.0	17.5	-	270	380	3.10
1557	25.0	14.5	-	21.5	30.5	3.15
1130	End of Start					
1145	26	[illegible]	0	22	30	0
1200	31	17.5	-	28	37	22
1215	31	17	-	28	36.5	26
1230	31	17	-	28	36.5	30
1350	31	17	-	28	36.5	30
1410	30	19	0	30	37	0
	31	17	-	28	36.5	30

T/C THERMOCOUPLES °F

Time of Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1700	160	162	91	159	148	159	159	155	159	155	159	79	77	77	78	80	83	82	81
1725	160	161	102	163	145	164	164	157	163	162	163	88	82	83	91	85	82	77	92
1745	160	161	102	160	142	164	164	154	160	162	161	87	87	89	83	86	82	78	92
1805	160	161	106	161	143	173	174	158	162	173	171	92	93	95	86	94	92	84	102
1810	160	161	105	160	141	175	175	157	161	174	170	96	97	98	87	97	96	87	104
0955	160	161	95	161	150	160	161	150	160	157	159	82	83	83	80	80	82	81	82
1010	161	162	96	162	142	173	174	152	163	172	167	84	84	84	81	91	88	82	98
1020	160																		
1040	161	162	104	163	141	216	212	157	167	211	201	97	97	97	91	116	102	102	114
1055	160	161	105	162	142	219	214	157	164	214	203	102	104	104	94	124	107	109	121
1540	160	161	90	161	143	160	160	146	160	154	159	93	98	97	89	96	94	93	97
1555	162	162	99	162	145	219	215	156	167	213	202	97	98	100	91	115	114	102	113
1557	163	163	103	160	145	220	218	154	164	217	202	104	[illegible]	104	93	122	120	107	119
1600	164	164	106	161	144	224	222	156	166	221	205	109	107	107	95	124	124	110	121
1110	164																		
1130	-END OF DEZ QCSEE-15	NEW DEZ QCSEE	N	Sun Gear	Letter "B"														
1145	160	160	93	161	160	161	161	156	161	152	158	78	77	77	77	77	80	80	79
1200	162	162	93	160	162	176	176	156	160	171	169	79	77	78	77	87	87	80	92
1215	165	166	100	170	163	235	232	166	165	226	212	87	82	81	109	110	108	96	109
1230	161	162	103	162	163	237	233	168	166	231	215	93	93	85	86	124	124	110	121
1350	161	162	101	162	163	238	235	168	168	233	216	97	94	97	90	129	130	115	126
1410	- Dynamometer Drive -																		
	162	161	95	163	131	163	159	154	163	166	163	89	86	86	92	110	92	89	99
	162	162	94	162	166	232	229	159	166	226	215	93	96	97	92	120	121	107	107

MET-ER METERS

Time of Day										Vibr. mils 1	2
1700	[illegible]		368		–	–	448		53		
1725	1570	1500	364	382			440	[illegible]	57	1.0	.01
1745	925	8650	318	[illegible]			261	[illegible]	27	1.0	.05
1805	1570	[illegible]	367	382			440	[illegible]	51	.07	.09
1810	1170	[illegible]	281	320			325	[illegible]	37	.08	.09
0955	[illegible]	1500	306	2700	–	–	442	[illegible]	50		
1010	1570	1800	351	2740	–	–	440	[illegible]	53	.03	.07
1040	1570	1500									
1055	1570	1500	352	3700	–	–	440	[illegible]	50	.02	.04
1540	1430	[illegible]	322	3000	–	–	403	[illegible]	45	.01	.03
1555	1570	1500	344	[illegible]			441	[illegible]	52		
1557	[illegible]	[illegible]	319	3090			402	[illegible]	47	.07	.03
1600	[illegible]	1200	[illegible]	2180			355	[illegible]	41	.08	.02
1110	1170	[illegible]	248	[illegible]			315	[illegible]	35	.08	.02
1145	1262	[illegible]	277	2160							
1200	1261	[illegible]	[illegible]	[illegible]			315	[illegible]	42		
1215	1261	[illegible]	[illegible]	2180			317	[illegible]	42	.5	.7
1230	1261	[illegible]	280	[illegible]			317	[illegible]	42	5.0	12.0
1350	1261	[illegible]	[illegible]	[illegible]			317	[illegible]	42	1.8	6.9
1410	1262		277	2160			317	[illegible]	42	1.7	6.7
	1261	[illegible]	276	2160			317	[illegible]	41	2.1	10.0

1st Shift / 2nd Shift / 3rd Shift
Engineer O.W. [illegible]
Tester Y. P. [illegible]
Observer C. A. O'[illegible]
Inspector

#2

CURTISS-WRIGHT CORPORATION
POWER SYSTEMS LOG
TEST OBJECTIVE

BUILD NO. 6
PROJECT NO. 660445
Reduction Gear Back to Back, Run w/Step Load Survey

DATE May 6, 1976 STAND NO. W1238 ENGINE MODEL QCSEE-15 NO. OTW SHEET NO. 2

Time of Day	AM/PM	Start/Stop	← T/C THERMOCOUPLES °F → 25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	VIBRATION READINGS mils 1	2	3	4	5	6	7	8	9
1620		Start	161	161	161	161	161	162	55	161	161	160	160	160	160	83	160	80									
1700			166	166	165	164	164	164	-	164	164	164	164	164	165	85	86	86									
1725			166	166	166	165	164	165	-	165	164	164	164	165	165	86	56	87									
1745			176	175	175	174	175	175	-	178	173	173	173	174	174	88	88	88	[illegible]	[illegible]	.04	[illegible]	[illegible]	.020	-	-	.30
1805			178	177	177	176	177	176	-	180	175	175	175	176	175	88	89	89	.4	.06	-	.020	.08	.050	-	-	.20
1810		Stop																	.06	.013		.04	.05	.05			.05
0920		Start	161	162	162	163	159	162	161	161	161	161	161	161	161	162	162	162	.06	.42	-	.03	.05	.67			.04
0955			176	176	176	175	176	176	176	178	174	174	174	175	174	173	174	173									
1010		Stop																									
1020		Start																	.07	1.4	-	.09	.05	1.7	-	-	4.2
1040			213	212	212	212	216	213	213	221	206	206	206	210	207	205	205	205									
1055			215	214	215	214	219	216	218 216	228 227	210	208	209	212	209	207	209	208									
1100		Stop																	1.2	-	-	.06	2.1	2.2	-	-	6.3
1510		Start	161	162	162	161	161	162	162	162	161	162	162	162	162	162	162	162	1.2	-	-	.05	2.1	2.2	-	-	6.4
1530			216	214	215	214	219	216	216	225	210	209	209	213	211	208	209	208									
1540			219	218	218	217	222	219	219	228	214	212	213	216	215	211	213	212									
1555			222	222	222	221	227	222	223	233	218	216	217	221	219	215	217	216	1.0	1.9	-	.03	1.0	1.1	-	-	6.4
1557																			1.0	1.4	-	.039	1.0	1.3	-	-	6.6
1600		Stop																	1.0	1.4	-	.04	1.0	1.3	-	-	6.9
1110	AM	Start	177	177	177	177	177	177	177	180	175	175	175	176	110	175	175	175									
1130			179	179	179	178	179	179	179	183	176	176	176	177	176	176	176	176									
1145			230	228	227	227	235	230	229	240	223	221	222	226	224	220	222	221									
1200	PM		233	232	[illegible]	231	239	233	233	245	236	226	226	230	226	223	225	225									
1215			234	233	233	232	240	235	235	246	227	226	227	231	-	226	226	225									
1220	PM	Stop																									
1350		Start	152	152	154	153	154	154	156	156	155	155	156	156	110	157	158	159									
1410			230	228	227	227	235	230	230	241	223	221	223	227	-	220	221	221									

1st Shift / 2nd Shift / 3rd Shift
Engineer [illegible]
Tester V.P. [illegible]
Observer C. A. Co[illegible]
Inspector

ORIGINAL PAGE IS
OF POOR QUALITY

TEST OBJECTIVE Reduction Gear Back to Back Run-in - Step Load Survey PROJECT NO 668441

Build #6 #7

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 5-14-76 STAND NO W-27R ENGINE MODEL QCSEE-16 DTW SHEET NO 3

TIME OF DAY	Start / Stop	Time	RPM	HP	Amps	Volts				Load HP	Red Gear Unit	Test Unit AOE	CAL	3	4	5
7778			1938	359	1100	240	6200	3800	385	315	9008	31	17	-	28	36.5
1430			1946	358	1150	240	6280	4060	400	475	13349	31	17	-	28	36.5
1435	Stop	5¹³														
1835	Start	5¹⁴	Static Running													
1900												29	17		26	35
1915			1820	308	1000	240	6000	3820	309	315	8410	31	16.5	-	28	36
1925			1820	346	1025	240	6000	4060	386	376	[illegible]	31	17.5	-	28	36.5
1935			1819	359	1100	240	6000	4060	390	316	[illegible]	31	17.5	-	28	36.5
1945			1878	359	1160	240	6190	4000	406	316	[illegible]	31	17.2	-	28	35
1950	Stop	7⁴⁵	1946	358	1150	240	6200	4050	401	316	[illegible]	31	17.5	-	28	35
1425	Start	7⁴⁵	Static Running													
1500			1946	362	1150	240	6202	4035	410	315	1384	30	18	-	27	36
1505	Stop											30	17.5	-	27	36
6-9-76	DEI QCSEE-16 ENDURANCE TEST															
1550			Static Running						50			20	16	0	27	37
1600	Start	7⁴⁵														
1620			918	722	220	245	3030	1690	81.25	74	1662	28	15.5	-	25	33.5
1635			918	95	300	245	3030	2230	107	315	4265	30	17		27.5	36.5
1700			1242	147	450	245	4000	2700	171	315	5610	30	16.8		27.5	36.5
1720			1576	240	730	245	5200	3280	271	315	7380	30	17		27.5	36.5
1740			1934	373	1150	242	6382	4100	415	315	9983	30	17		27.5	36.5
1800			1937	379	1200	242	6382	4210	427	400	11026	30	17		27.5	36.5
1820			1942	389	1200	242	6400	4400	426	400	11034	30	17		27.5	36.5
1840			1921	389	1200	242	6400	4200	425	474	13529	30	17		27.5	36.5
1850			1576	254	800	242	5200	3560	344	474	[illegible]	30	17		27.5	36.5
1900			1242	168	520	242	4000	3000	190	474	8473	30	17		27.5	36.5
1910	STOP	8⁰⁵														
6-10-76																
0955	Start	8⁰⁵	Static Running						50			20	16.5		17	26
1000		8²⁵	722													
1015			918	[illegible]		245	[illegible]			74	[illegible]	20	5		17	25
1030			918	72.8	220	245	[illegible]			74	[illegible]	20	5		17	25
1045		8³⁵	918	72.2	220	245	[illegible]			74	[illegible]	20	5		17	25
1100			918	72.2	220	245	[illegible]			74	[illegible]	20	5		17	25.5
1115			918	72.2	220	245	[illegible]			74	[illegible]	20	5		17	25.5
1130	12³⁰	1³⁹	918	72.2	220	245	[illegible]			74	[illegible]	20	9		17	25.5

— Gear Inspection —

— Scheduled Shut Down —

— Scheduled Shut Down — Removed unit 6/8/76 Reinstalled unit – Reassembly of unit includes oil baffle, oil manifold modification, installation of C.E. oil scavenge and [illegible] for [illegible] 2.24 GPM [illegible] to the test unit and oil outlet. Build #7 [illegible] of oil tank 370 (QD)

1st SHIFT 2nd SHIFT 3rd SHIFT

ENGINEER ~ Misel

TESTER Durant Vreeland

OBSERVER

INSPECTOR

TEST OBJECTIVE Reduction Gear Back to Back Run-in - Step Load Survey PROJECT NO 668441

Build #6

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 5-14-76 STAND NO W-27R ENGINE MODEL QCSEE-16 DTW SHEET NO 4

TIME OF DAY	Start / Stop	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	1 Input Vert	2 Horiz	3	4	5	6	7	8	9
7778		226	228	227	227	234	230	230	141	223	221	223	227	-	220	221	221									
1430		233	232	231	231	238	234	234	246	227	225	226	231	-	223	225	224									
1435	Stop																	2.2	6.0	-	.7	2.9	.57	-	-	590
1835	Start	159	160	160	160	159	160	161	163	161	162	163	166	166	166	167	167									
1900		221	222	223	222	228	-	223	232	219	217	218	221	218	216	217	216									
1915		225	226	226	226	231	-	227	236	222	220	220	225	220	219	220	220	.95	2.7	-	.6	2.2	2.2	-	-	140
1925		226	228	228	227	233	-	228	238	224	222	222	227	222	221	222	221	1.3	2.8	-	.55	1.3	2.6	-	-	200
1935		230	231	232	230	236	-	231	241	226	224	225	229	226	222	226	223	1.5	3.6	-	.6	2.5	2.8	-	-	195
1945		233	236	234	233	240	-	235	245	229	227	227	232	229	225	227	226	2.3	5.5	-	.7	3.0	4.8	-		430
1950	Stop																	2.7	4.0	-	.9	1.7	3.9	-		480
1425	Start	161	162	163	162	161	161	161	161	161	161	161	161	160	161	161	161									
		226	227	228	226	234	-	228	238	222	220	221	225	194	219	220	219									
1505	Stop																	.06	2.5	.	.08	.8	1.3			2.5
6-9-76	DEI QCSEE-16																									
1600	Start																									
1620		180	180	180	180	180	180	106	179	178	178	178	178	179	178	178	179	9	9		10	8	6			7
1635		185	185	184	184	184	185	111	184	183	183	183	182	184	183	183	184	1.1	2.3		.35	.45	1.2			6.3
1700		194	194	194	195	195	195	-	194	192	192	192	191	192	192	192	194	1.0	1.9		.42	.56	1.1			8.0
1720		211	211	214	214	217	215	-	212	210	208	208	207	211	208	208	212	2.4	3.6		.80	2.6	2.5			3.0
1740		224	222	226	226	230	228	-	223	220	218	219	217	221	218	218	223	.78	1.4		.73	2.2	1.5			3.6
1800		230	227	231	231	234	233	-	228	224	223	224	222	226	223	223	225	2.0	1.0		.38	.69	1.3			4.8
1820		232	226	231	231	234	233	-	227	225	223	224	222	226	223	223	227	1.5	1.0		.45	.61	1.2			4.0
1840		230	228	232	232	234	234	-	226	227	224	225	223	227	224	224	230	1.5	.92		.36	.60	1.7			4.0
1850		210	211	213	213	216	214	-	211	208	206	207	205	209	206	207	211	No Rdg.								
1900		196	196	197	197	199	198	-	197	193	192	192	190	192	191	191	194									
1910	Stop																									
6-10-76																										
0955	Start																									
1000		181	181	180	181	181	181	181	183	180	180	179	178	178	178	179	180									
1015		181	181	180	181	181	181	181	181	180	180	179	178	178	178	179	180	1.4	2.0	-	.36	.40	1.4			5.0
1030		181	181	180	181	180	181	181	181	179	180	179	178	178	178	179	180	1.4	2.3		.32	.40	1.4			5.0
1045		181	181	181	181	181	181	181	182	179	179	179	178	178	178	179	180	1.1	1.4		.32	.42	1.5			5.4
1100		181	181	181	181	181	181	181	182	180	179	179	178	178	178	179	180	1.0	2.4		.33	.41	1.5			5.5
1115		180	181	181	181	181	181	181	181	179	179	179	178	178	178	179	181	1.0	2.3		.33	.42	1.5			5.5
1130		180	181	181	181	181	181	181	181	179	179	179	178	178	178	179	181	1.0	1.3		.32	.42	1.6			5.3
																		1.0	2.3		.33	.42	1.6			5.3

1st SHIFT 2nd SHIFT 3rd SHIFT

ENGINEER ~ Misel ~

TESTER Durant

OBSERVER

INSPECTOR

TEST OBJECTIVE [illegible] Gear Box to Back [illegible] ENDURANCE TEST PROJECT NO 660445

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 6/10/76 STAND NO [illegible] ENGINE MODEL [illegible] OTW SHEET NO 5

TIME OF DAY																																												
1130		9.8	72.2	220	245	3030	1550	74.5	74	.1002	20	9	17	255	21	163	162	105	163	144	179	179	153	166	177	173	108	108	107	99	107	104	94	110	951	[illegible]	215	1840	268	990	31	125	.56	.35
1145		9.8	72.2	220	245	3030	1550	74.5	74	.1002	20	9	17	255	21	163	162	106	163	145	179	179	152	166	177	173	110	110	109	100	107	104	94	110	950	9494	218	1840	260	990	31	125	.56	.30
1200	2^{05}	9.8	72.2	220	245	3030	1550	74.5	74	.1002	20	9	17	255	21	103	162	105	163	145	180	179	152	166	177	173	110	111	110	102	108	103	94	110	950	9492	230	1840	268	990	31	125	.56	.35
1225	2^{25}	1940	388	1080	240	6400	3750	381	315	9009	25	14	22	30	33	160	113	112	160	143	230	228	128	163	225	207	118	118	117	129	128	128	112	126	1140	[illegible]	[illegible]	[illegible]	320	[illegible]	39	148	1.8	.7
1250		1940	388	1080	240	6400	3750	381	315	9009	25	14	22	30	33	161	160	117	161	143	231	225	128	162	226	41	120	122	125	111	110	131	116	128	1140	[illegible]	282	[illegible]	320	[illegible]	39	148	1.8	.7
1305		1940	384	1080	240	6400	3720	378	315	9009	25	15	22	30	33	161	162	113	163	144	234	232	125	163	227	212	122	124	124	114	124	122	130	133	1140	[illegible]	282	[illegible]	320	[illegible]	38	145	2.0	.8
1320		1940	387	1080	240	6400	3720	378	315	9009	25	15	22	25	33	160	160	121	163	144	233	231	124	166	229	211	127	128	133	117	126	127	132	134	1140	[illegible]	[illegible]	[illegible]	320	[illegible]	38	145	1.9	.8
1335		1940	347	1080	240	6400	3720	378	315	9009	26	14	22	30	33.5	162	162	119	162	145	233	231	128	162	229	211	127	129	126	132	137	129	132	135	1140	[illegible]	[illegible]	[illegible]	320	[illegible]	38	145	1.9	.8
1350		1940	347	1080	240	6400	3720	378	315	9009	26	14	22	30	33.5	161	160	120	163	145	233	230	128	164	229	210	131	133	126	125	134	137	124	136	1140	[illegible]	[illegible]	[illegible]	320	[illegible]	38	145	1.9	.8
1405		1940	347	1080	240	6400	3720	378	315	9009	26	14	22	30	33.5	161	161	120	163	145	230	231	126	165	229	211	130	133	127	125	138	140	124	136	1140	[illegible]	278	[illegible]	318	[illegible]	38	145	1.5	.8
1420		1940	347	1080	240	6400	3720	378	315	9009	26	14	22	30	33.5	161	160	120	163	145	234	231	130	165	229	211	130	133	127	125	138	126	125	136	1140	[illegible]	278	[illegible]	319	[illegible]	38	145	.7	.4
1435	4^{00}	1940	347	1080	240	6400	3720	378	315	9009	26	14	22	30	33.5	161	161	120	163	145	234	230	125	165	229	211	130	133	126	125	138	126	124	136	1140	[illegible]	278	2170	339	[illegible]	[illegible]	145	.7	.4
1445	STOP 4^{15} DYN. ROCKER OUT @ 6517 RPM. - Shutdown for Gear inspection OIL SCALE STATIC COLD = 448 OIL STATIC HOT = 348																																												
1010	START 6-11-76																																											
1020	START 10^{25}										25	15	23	31		163	163	107	163	148	162	163	111	163	158	157	90	90	90	87	87	88	88	88	1140	1020	278	2110	318	1200	39	148		
1030	10^{35}	1940	347	1080	240	6400	3730	378	315	9008	25	15	23	31	5																				1140		278		318		39			
1045	4^{00}	1940	347	1080	240	6400	3730	378	315	9008	26	14	23	30	28	161	161	102	161	142	217	216	110	166	210	207	92	92	95	90	98	96	92	101	1140	1200	278	2100	320	1200	39	148	1.9	.43
1100		1940	347	1150	238	6400	[illegible]	408	474	1355	26	14	23	30	30	161	161	105	163	142	215	232	115	168	225	211	100	96	101	98	119	102	105	116	1140	1200	278	2100	320	1200	39	148	2.6	.7
1115		1940	367	1150	238	6400	4020	408	474	1355	28	15.5	25	33	33	161	161	107	161	144	236	234	113	164	229	212	109	105	107	106	130	107	116	127	1212	1600	296	2300	339	1250	41	150	1.5	.7
1130	10^{55}	1940	367	1150	238	6400	4020	408	474	1355	28	15.5	25	33	33	161	161	110	161	145	236	232	117	164	230	212	116	111	112	113	135	110	120	131	1212	1600	296	2300	339	1250	41	150	1.3	.56
1145	5^{00}	1940	367	1150	238	[illegible]	4020	408	474	1355	28	15.5	25	33	33	161	161	111	160	146	230	232	118	164	230	212	121	116	116	117	137	111	123	135	1212	1600	296	2300	339	1250	41	150	1.2	[illegible]
1200		1940	367	1150	238	6400	4020	408	474	1355	28	15.5	25	33	33	161	101	112	160	146	235	231	118	163	230	212	124	120	122	118	138	112	124	136	1212	1600	296	2300	339	1250	41	150	2.7	.5
1215		1940	367	1150	238	6400	4020	408	474	1355	28	15.5	25	33	33	161	161	112	162	146	236	231	118	163	230	212	127	124	126	122	139	112	124	136	1212	1600	296	2300	339	1250	41	150	2.7	.5
1230	10^{15}	1940	367	1150	238	6400	4020	408	474	1355	28	15.5	25	33	35	161	161	112	162	146	236	232	118	163	230	213	130	126	129	125	139	113	124	137	1212	1600	296	2300	339	1250	41	150	2.7	.5
1245	10^{30} 6^{00}	1940	367	1150	238	6400	4020	408	474	1355	28	15.5	25	33	33	161	160	113	162	146	235	232	120	164	230	212	131	129	132	128	140	113	125	137	1212	1600	296	2300	339	1250	41	150	1.8	.5
1250	STOP 10^{45} SHUTDOWN FOR GEAR INSPECTION. OIL SCALE STATIC COLD = 426 HOT = 338										28	15.5	25	33	33	161	161	113	162	146	236	232	122	164	230	213	133	131	134	129	140	113	125	137	1212	1600	296	2300	339	1250	44	150	2.6	.35
0930	STATIC 10^{45} 6-14-76																																											
0935	START 10^{45}										25	15	23	30.5		161	161	95	162	146	161	161	115	161	158	158	77	76	76	76	76	81	81	77	1140		279		318		38			
0945		1940	399	1050	248	6400	3730	378	315	9008	25	15	23	31	5																				1140		278		318		38			
1000	6^{00}	1940	389	1050	248	6400	3730	378	315	9008	25	14	23	30	25	161	161	96	164	136	230	224	105	166	213	210	79	77	80	79	92	99	87	93	1140	1200	282	2196	318	1200	38	145	1.8	.5
1015		1940	394	1200	245	6400	4200	430	516	14757	25	14	23	30	24	161	162	109	165	137	235	233	112	167	226	212	86	82	88	86	113	113	100	110	1140	1200	282	2196	318	1200	38	145	2.5	.6
1030		1940	394	1200	245	6400	4200	426	516	14757	30	16.5	26	36	33	162	163	105	165	142	241	234	106	167	232	215	96	90	92	94	125	126	110	121	1260	1200	313	2420	350	1200	43	153	2.1	.6
1045		1940	394	1200	245	6400	4200	426	516	14757	30	16.5	26	36	33.5	161	162	100	163	142	237	232	107	164	230	213	104	97	99	101	131	133	117	127	1260	1200	313	2420	350	1200	43	153	1.6	.5
1100	7^{00}	1940	394	1200	245	6400	4200	426	516	14757	30	16.5	26	36	33.5	161	161	97	162	142	236	232	108	165	230	213	106	101	105	105	133	135	120	130	1260	1200	313	2420	350	1200	43	153	1.6	.5
1115		1940	394	1200	245	6400	4200	426	516	14757	30	16.5	26	36	33.5	162	162	97	161	143	236	232	120	164	230	212	110	104	108	106	134	136	120	131	1260	1200	313	2420	350	1200	43	153	1.6	.5
1130	9^{30}	1940	394	1200	245	6400	4200	426	516	14757	30	16.5	26	36	33.5	161	161	97	162	143	236	232	120	163	230	212	113	110	113	109	135	137	122	132	1260	1200	313	2420	350	1200	43	153	2.1	.9
1135	STOP 20^{12} 7^{30} SHUTDOWN FOR GEAR INSPECTION. OIL SCALE STATIC HOT = 312										30	16.5	26	36	33.5	161	161	97	162	143	236	232	120	163	230	212	113	110	113	109	135	137	122	132	1260	1200	313	2420	150	1200	43	153	2.1	.9

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER	~	[illegible]	~
TESTER	[illegible]		
OBSERVER	[illegible]		
INSPECTOR	[illegible]		

6-11-76

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6-14-76

TEST OBJECTIVE [illegible] Gear Box Back to Back [illegible] ENDURANCE PROJECT NO 660445

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 6/10/76 STAND NO [illegible] ENGINE MODEL [illegible] OTW SHEET NO 6

TIME OF DAY		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	
1130		180	181	181	181	181	181	181	181	179	179	179	178	178	178	179	181						
1145		180	181	181	181	181	181	181	181	179	179	179	178	94	178	179	181	1.0	2.3	.30	.42	1.6	5.3
1200		180	181	181	181	181	181	181	181	179	179	179	178	94	178	179	181	1.0	2.3	.33	.42	1.5	5.8
1235		223	224	227	228	233	236	228	225	223	220	221	219	223	220	220	225	1.0	2.3	.33	.42	1.5	5.8
1250		223	224	227	228	233	230	228	225	223	220	221	219	224	224	224	226	1.7	1.0	.38	.40	2.6	4.2
1305		226	227	231	231	236	233	231	229	226	223	224	222	224	223	223	228	1.7	1.0	.35	.40	2.0	4.3
1320		225	226	230	230	235	236	230	227	225	222	223	221	226	222	223	227	1.2	1.0	.36	.40	1.9	4.4
1335		225	224	231	231	236	235	232	226	224	223	224	223	227	223	223	228	1.2	.05	.38	.42	3.1	4.0
1350		225	226	232	230	236	232	232	228	224	223	224	224	226	223	223	228	1.2	1.0	.38	.42	3.1	4.3
1405		225	227	230	231	236	233	231	228	226	227	223	222	226	223	223	227	1.7	1.0	.37	.40	2.0	4.3
1420		225	228	230	230	230	234	230	226	226	223	222	222	227	223	223	227	1.6	0.9	.43	.31	3.0	4.0
1435		225	227	230	230	235	234	231	228	226	222	222	222	226	223	223	228	1.6	0.1	.43	.40	3.0	4.1
1445	STOP																	1.6	0.6	.42	.40	3.0	4.1
1010	STATIC	163	162	163	163	163	163	163	163	163	163	163	163	163	163	163	163						
1020	START																						
1030		225	227	230	230	236	232	231	229	224	215	211	220	223	223	222	227						
1045		230	230	231	230	236	232	231	230	225	224	224	222	226	227	223	228	1.4	.72	.46	1.2	1.4	3.0
1100		232	232	232	232	237	234	233	232	227	224	223	223	227	224	225	230	1.4	.80	.50	.62	1.4	3.0
1115		232	232	232	233	237	234	233	232	227	225	226	223	228	225	225	230	1.3	.72	.46	.62	2.6	3.1
1130		232	232	232	233	237	235	234	232	227	225	226	224	228	225	225	230	1.2	.82	.43	.59	2.2	3.2
1145		232	232	232	233	237	234	233	231	227	224	225	223	227	224	224	229	1.5	.88	.43	.61	3.7	3.5
1200		232	232	232	233	237	234	233	231	227	224	225	223	227	224	224	229	1.5	.91	.43	.71	3.4	3.6
1215		232	234	232	233	237	234	233	231	227	224	225	223	227	224	224	230	1.35	.90	.40	.66	1.9	4.0
1230		232	232	232	233	237	234	233	231	227	224	225	223	227	224	224	230	1.3	.88	.40	.59	.72	3.9
1245		232	232	232	233	237	234	233	231	227	224	225	223	227	224	224	230	1.3	1.0	.43	.63	[illegible]	4.2
1250	STOP																	1.9	.90	.40	.56	.70	3.9
0930	STATIC	163	162	163	162	162	162	162	162	162	162	162	163	163	163	163	163						
0935	START																						
0945		225	226	230	230	236	232	230	228	225	223	224	218	221	223	223	228						
1000		229	224	232	232	238	233	232	230	227	224	225	223	228	223	225	230	1.6	.90	.50	.70	1.0	4.0
1015		234	231	236	235	238	237	236	234	230	228	228	226	231	226	227	234	1.6	.82	.51	.59	1.0	4.0
1030		232	232	232	232	237	235	233	234	228	225	226	224	229	225	225	231	1.3	.93	.46	.71	1.3	3.6
1045		232	232	232	232	237	236	234	232	228	225	226	224	229	225	224	231	1.4	.96	.42	.61	1.0	3.4
1100		232	232	232	234	237	234	233	232	227	225	225	223	228	225	225	230	1.4	1.1	.44	.60	1.7	3.3
1115		232	232	232	232	237	234	233	232	227	225	225	223	228	225	225	230	1.3	.96	.42	.61	1.2	3.4
1130		232	232	232	234	237	234	233	232	227	225	225	223	228	225	225	230	1.4	.98	.43	.61	1.0	3.4
1135	STOP																	1.4	1.0	.47	.40	1.3	3.4

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER	~	[illegible]	~
TESTER	[illegible]		
OBSERVER	[illegible]		
INSPECTOR	[illegible]		

6-11-76

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6-14-76

ORIGINAL PAGE IS OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

#1

TEST OBJECTIVE Reaction Gear Back-to-Back [illegible] ENDURANCE PROJECT NO. 668 445

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 6-14-76 STAND NO. 6X376 ENGINE MODEL QCSEE-UTW NO. 07-1 SHEET NO. 1

TIME OF DAY	START & STOP		
1435	STATIC		SHUTDOWN FOR GEAR INSPECTION — OIL SEAL STATIC HOT = 312
1430	START 20		
1440			
1455			
1455	STOP 20		
1505	START 20		SHUTDOWN DYE OVERLOAD STOP
1510			
1525			
1540			
1555			
1610			
1615	STOP 21		SHUTDOWN FOR GEAR INSPECTION

7-7-76 DEI QCSEE-17 BUILD No 7A OIL CHURNING INVESTIG.

TIME OF DAY	START & STOP	
1030	STATIC	OIL SEAL STATIC HOT = 318
1040	START 21	
1055		
1110		
1125		
1140		
1155		
1220		
1235		
1255		
1310	STOP 24	DOWN CUT OUT — PERFORM GEAR INSPECTION

7-8-76

TIME OF DAY	START & STOP	
0955	START 24	OIL SEAL STATIC HOT = 312
1000		
1015		
1035		
1050		
1100		
1110		
1125		
1135		
1145	STOP 26	

ENGINEER
TESTER Durant
INSPECTOR

#8

TEST OBJECTIVE Reaction Gear Back-to-Back ~~[illegible]~~ Oil Churning Investig. & ~~[illegible]~~ PROJECT NO. 668445

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 6-14-76 STAND NO. 6X376 ENGINE MODEL QCSEE-UTW NO. 07-1 SHEET NO. 2

TIME OF DAY	START & STOP	T/C 1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	VIB 1	2	3	4	5	9
1415	STATIC	140	142	142	138	136	137	139	142	139	140	141	143	143	143	144	145						
1430	START																						
1440		226	228	232	231	236	233	232	229	226	225	224	219	222	224	224	229						
1455		225	226	230	230	235	231	230	229	225	224	223	221	225	222	222	226	1.6	.88	.58	1.0	2.0	3.3
1455	STOP																	1.4	1.0	.46	.71	1.0	3.8
1505	START																						
1510		226	227	230	230	233	232	230	228	223	222	222	217	220	222	222	228						
1525		226	227	230	230	233	232	230	228	223	222	222	217	220	222	222	228	1.5	.92	.34	.72	1.0	3.5
1540		230	227	230	230	233	232	230	228	225	222	223	222	226	222	222	228	1.7	.88	.35	.78	1.1	4.0
1555		226	227	230	229	232	231	229	228	225	222	223	222	226	222	223	228	1.6	.90	.35	.70	1.0	4.0
1610		226	227	230	229	232	231	229	228	225	222	222	222	226	222	222	228	1.7	1.0	.36	.78	.92	3.8
1615	STOP																	1.6	1.0	.36	.78	.92	3.8

7-7-76 DEI QCSEE-17

TIME OF DAY	START & STOP	
	STATIC	160 160 160 160 160 161 161 161 160 160 160 160 160 160 160 161
1040	START	
1055		[illegible]
1110		[illegible]
1125		[illegible]
1140		[illegible]
1155		[illegible]
1220		[illegible]
1235		[illegible]
1255		[illegible]
1310		[illegible]
1310	STOP	

7-8-76

TIME OF DAY	START & STOP	
	STATIC	[illegible]
0955	START	
1000		[illegible]
1015		[illegible]
1035		[illegible]
1050		[illegible]
1100		[illegible]
1110		[illegible]
1125		[illegible]
1135		[illegible]
1145	STOP	

ENGINEER
TESTER Durant
INSPECTOR

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TEST OBJECTIVE [illegible]
Oil Churning Investig.
PROJECT NO. 668445

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 2-8-76 STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. 9

TIME OF DAY

7-14-76

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER	[illegible]		
TESTER	[illegible]		
OBSERVERS	[illegible]		
INSPECTOR			

TEST OBJECTIVE [illegible]
Oil Churning Investig
PROJECT NO. 668445

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 2-8-76 STAND NO. [illegible] ENGINE MODEL [illegible] NO. [illegible] SHEET NO. 10

TIME OF DAY

	1ST SHIFT	2ND SHIFT	3RD SHIFT
ENGINEER	[illegible]	[illegible]	
TESTER	[illegible]		
OBSERVERS	[illegible]		
INSPECTOR			

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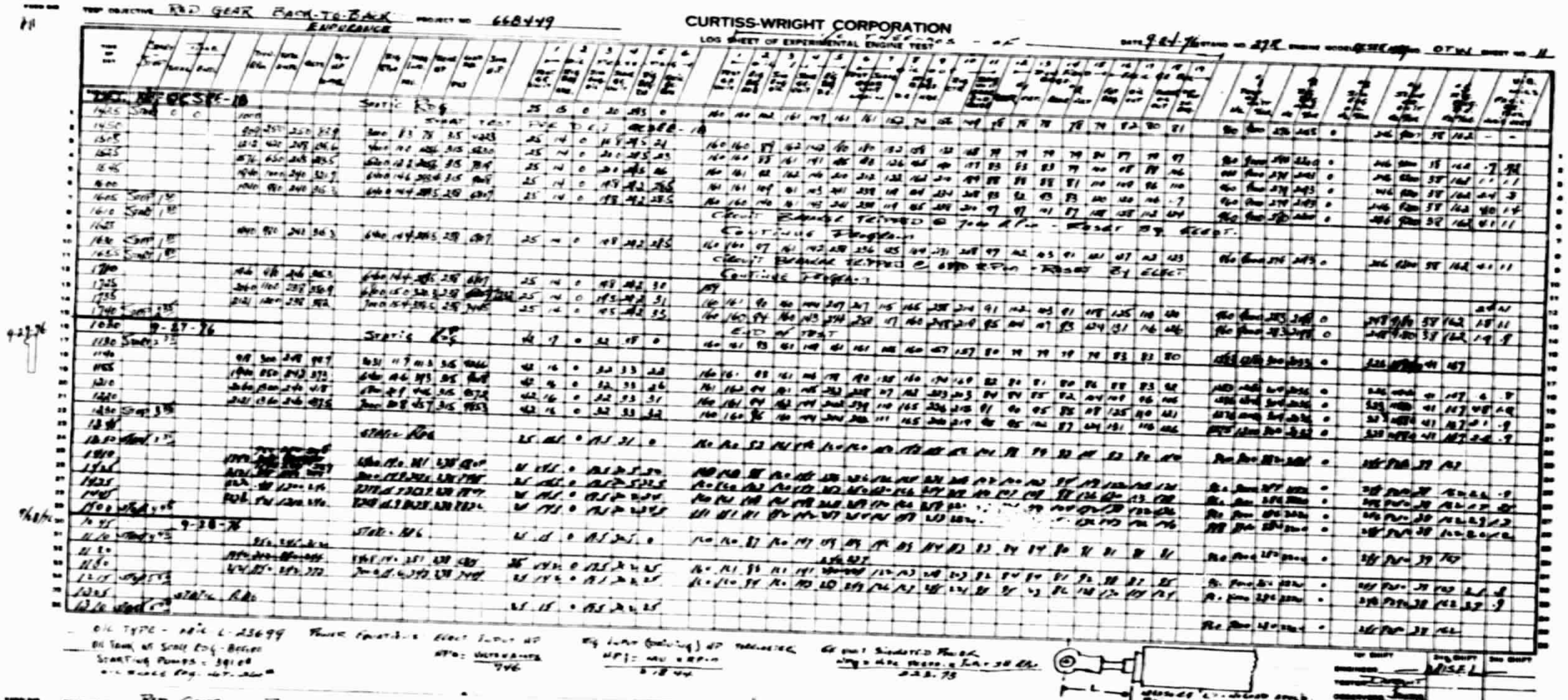
OF POOR QUALITY



TEST OBJECTIVE RED GEAR BACK-TO-BACK ENDURANCE PROJECT NO. 668449

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 9-21-76 STAND NO. 27R ENGINE MODEL [illegible] OTW SHEET NO. 11

Static Reg

Start test

Circuit breaker tripped @ [illegible] RPM - Reset by elect.

Continue program

End of test

9-27-76

9-28-76

Static Reg

OIL TYPE - MIL-L-23699

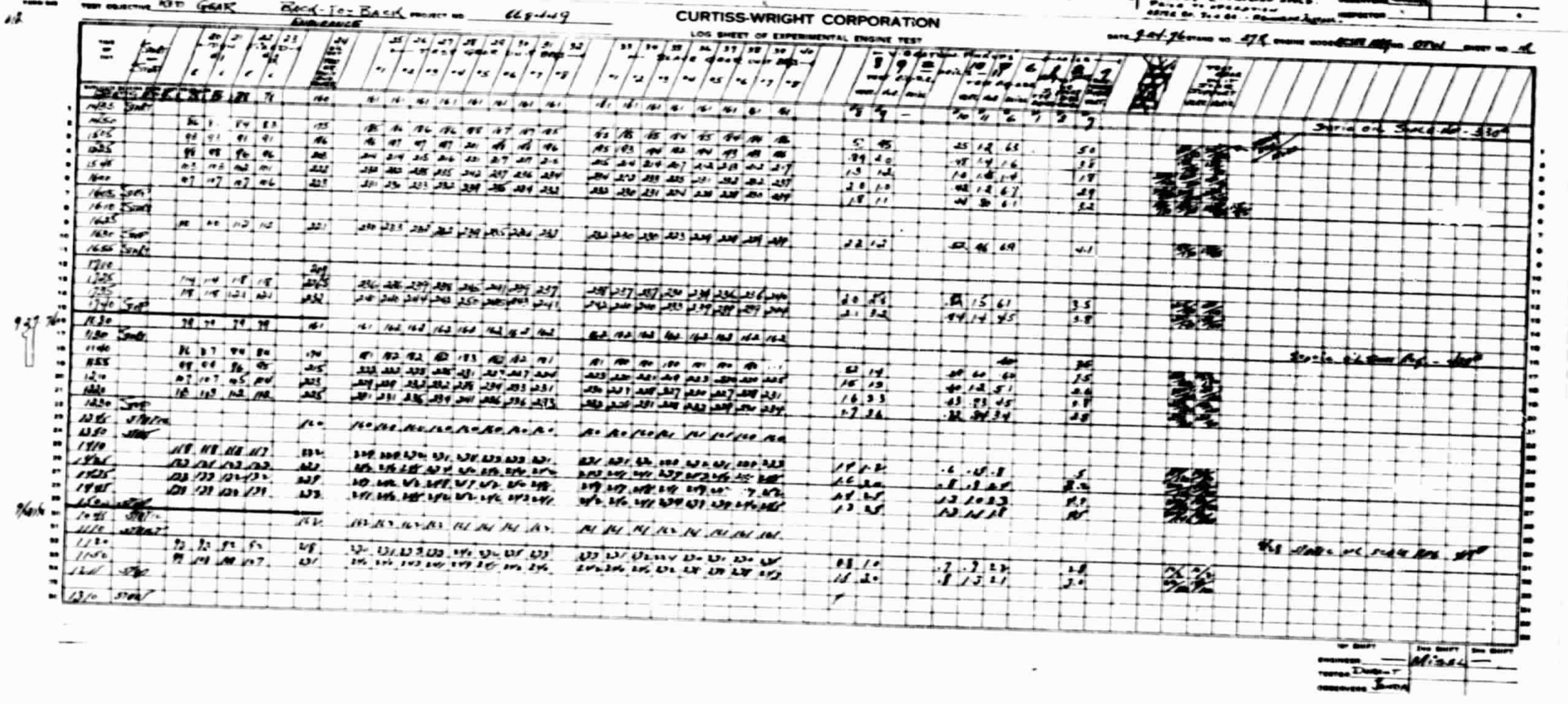
1ST SHIFT 2ND SHIFT 3RD SHIFT

ENGINEER

TESTOR

OBSERVERS

INSPECTOR



TEST OBJECTIVE RED GEAR BACK-TO-BACK ENDURANCE PROJECT NO. 668449

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE 9-21-76 STAND NO. 27R ENGINE MODEL [illegible] OTW SHEET NO. 12

1ST SHIFT 2ND SHIFT 3RD SHIFT

ENGINEER

TESTOR

OBSERVERS

#13

TEST OBJECTIVE Red Gear Back-To-Back PROJECT NO. 668449

ENDURANCE

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE [illegible] STAND NO. 178 ENGINE MODEL [illegible] OTW SHEET NO. 13

TIME
1320
1330
1340
1350
1400
1410
1420
1430
1435
1440
1450

End of Test

ENGINEER Rigel

TESTER [illegible]

OBSERVERS [illegible]

INSPECTOR

TEST OBJECTIVE Red Gear Back-To-Back PROJECT NO. 668449

ENDURANCE

CURTISS-WRIGHT CORPORATION

LOG SHEET OF EXPERIMENTAL ENGINE TEST

DATE [illegible] STAND NO. 178 ENGINE MODEL [illegible] OTW SHEET NO. 14

TIME
1310
1320
1330
1350
1400
1410
1420
1430
1435
1440
1450

End of Test

ENGINEER Rigel

TESTER [illegible]

OBSERVERS [illegible]

INSPECTOR

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